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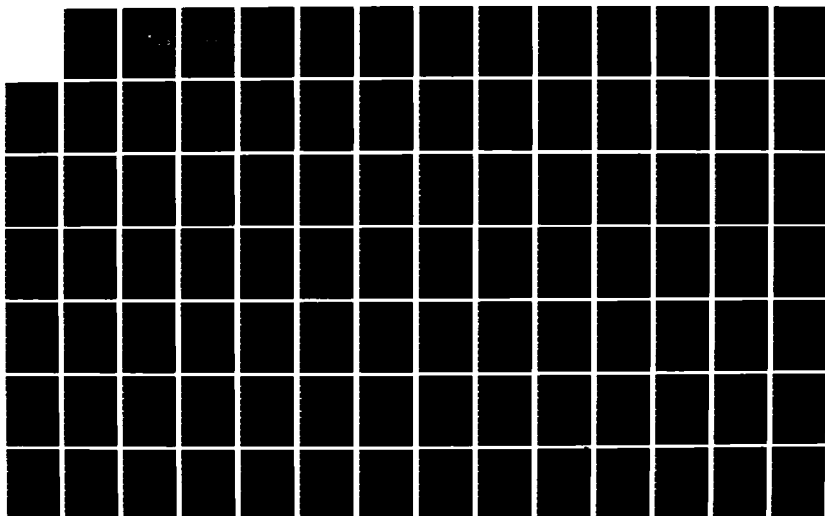
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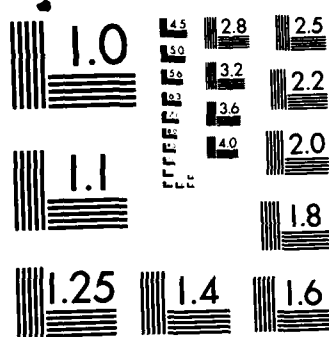
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THESIS

AVIATION WARRANTIES: THE COSTS AND RISKS

by

Robert Willard Savage

September 1985

Thesis Advisor:

D. C. Boger

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The study concludes that (1) across-the-board application of commercial aviation warranties to military aircraft procurements may not be proper, (2) no one warranty type is cost effective for every aircraft procurement, and (3) there is no standard pricing model that will work for every warranty situation.

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Aviation Warranties: The Costs and Risks

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The purpose of this research is to determine the types and characteristics of warranties used in commercial and military aircraft procurements. The research also includes a brief history of warranty development and Congressional legislation. The costs and risks associated with the use of warranties is discussed in generic form from the viewpoint of the Government and the contractor. Several warranty pricing models are presented, including the free-replacement warranty and the pro-rata warranty as viewed by the buyer and the seller, the rebate model, the prorated rebate model, and a look at using learning curves as a warranty support predictor.

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TABLE OF CONTENTS

I.	INTRODUCTION -----	8
A.	BACKGROUND-----	8
B.	FOCUS AND SCOPE OF THE RESEARCH-----	9
C.	RESEARCH QUESTIONS-----	9
D.	RESEARCH METHODOLOGY-----	10
E.	DEFINITIONS-----	10
F.	THESIS ORGANIZATION-----	12
II.	WARRANTY HISTORY AND LEGISLATION -----	13
A.	INTRODUCTION-----	13
B.	WARRANTY HISTORY-----	13
C.	CONGRESSIONAL INVOLVEMENT-----	15
D.	WARRANTY LEGISLATION-----	16
	1. The 1984 Act-----	17
	2. The 1985 Act-----	18
E.	SUMMARY-----	19
III.	TYPES OF WARRANTIES IN USE -----	21
A.	INTRODUCTION-----	21
B.	IMPLIED WARRANTIES-----	21
C.	EXPRESS WARRANTIES-----	22
D.	WARRANTIES IN USE-----	25
	1. The Reliability Improvement Warranty-----	25
	2. The Mean Time Between Failure Warranty-----	29
	3. The Mean Time To Repair Warranty-----	31

4. The Non-Warranty Warranty-----	31
5. The Standard Commercial Aviation Warranty-----	34
6. The Commercial/Military Aviation Warranty-----	40
7. The Military Aviation Warranty-----	42
E. SUMMARY-----	45
IV. WARRANTY COSTS AND RISKS -----	46
A. INTRODUCTION-----	46
B. COST/RISK TRADEOFFS-----	46
C. COSTS AND RISKS TO THE GOVERNMENT-----	49
D. COSTS AND RISKS TO THE CONTRACTOR-----	54
E. SUMMARY-----	60
V. WARRANTY PRICING MODELS -----	61
A. INTRODUCTION-----	61
B. WARRANTY MODELS-----	61
1. Blischke and Scheuer-----	62
2. Thomas-----	74
3. Barton-----	83
C. A SIMPLE NONANALYTIC MODEL-----	92
1. Step One--Product Warranty Scenario-----	93
2. Step Two--Product Warranty Task Statement-----	93
3. Step Three--Hardware Failure Rate/Documentation Deficiency-----	94
4. Step Four--Hardware and Documentation Cost/Correction--	94
5. Step Five--Summarize Quantity Based vs. Time Based Costs-----	95
6. Step Six--Itemize Assumptions and Exclusions-----	95
7. Step Seven--Determine Proposed Earnings-----	95

8. Step Eight--Develop a Historical Data Base-----	96
9. Conclusions-----	96
D. SUMMARY-----	96
VI. CONCLUSIONS AND RECOMMENDATIONS -----	99
A. CONCLUSIONS-----	99
B. RECOMMENDATIONS-----	101
APPENDIX A LOCKHEED L-1011 WARRANTY -----	104
APPENDIX B BOEING COMPANY WARRANTY -----	112
APPENDIX C McDONNELL DOUGLAS MD-80 WARRANTY -----	137
APPENDIX D McDONNELL DOUGLAS KC-10 WARRANTY -----	153
APPENDIX E McDONNELL DOUGLAS PROPOSED C-17 WARRANTY -----	165
LIST OF REFERENCES -----	193
INITIAL DISTRIBUTION LIST -----	196

I. INTRODUCTION

A. BACKGROUND

For many years manufacturers have conducted business on a cash and carry, no return basis. Once the customer took possession of the purchased item, seller's liability ceased. During the late 1950's and early 1960's, manufacturers introduced commercial product warranties in an attempt to outdo competitors and gain a larger share of the available market. This strategy seemed to work only until the competitors discovered the warranty and decided to match warranty coverage or attempt to cover their own products longer than competitors. It soon became apparent to the manufacturer that warranties could and would have a significant impact on corporate profit and many companies ceased offering warranties or offered only very short-term, limited liability coverage.

Trends of the late 1970's and early 1980's seem to indicate a return of longer and better warranty coverage. Because both private and public sector dollars seem more scarce, good business sense and survival instincts have forced the marketplace to provide better products and improved warranty coverage. Warranties have become a part of durables transactions as they are "expected" as an inclusion in nearly any purchase.

Over the years, the Department of Defense has not dealt with warranties or warranty issues with much tenacity. As a matter of fact, the Department of Defense has been cited on numerous occasions as paying the equivalent price as private industry for identical items, while not the receiving benefit of the warranty coverage that was provided to private enterprise. [1:1-2]

Additionally, attention has been directed toward defense contractors and their alleged inability to provide functional, durable weapons systems to the Department of Defense. As a consequence, Congress has mandated in both the 1984 and 1985 Defense Appropriations Acts the absolute requirement that a manufacturer's warranty be included as part of all Defense weapon systems acquisitions.

B. FOCUS AND SCOPE OF THE RESEARCH

The focus of this research is to examine in detail some aspects of warranties or warranty issues facing the Department of Defense. After a small amount of investigation, it quickly became clear that addressing warranties as a whole would be an impossible task for the time frame of this study. Initial research efforts led to the discovery that, as several authors had suggested, commercial aviation warranties had been used very effectively and successfully for years. Since the Department of Defense does not buy, or at least hasn't to any degree in the past bought, aircraft under the umbrella of a commercial aviation warranty, this researcher decided that an examination of the characteristics of the various types of aviation warranties used by the Department of Defense should be explored and compared to standard commercial aviation warranties.

C. RESEARCH QUESTIONS

The general research question of this study is:

What types of warranties are being used by the Department of Defense and the commercial aviation industry for aircraft procurements?

Specific research questions to be addressed in the study are:

1. What are the costs and risks of a warranty to the Government?

2. What are the costs and risks of a warranty to the contractor?
3. How can warranties be priced?

D. RESEARCH METHODOLOGY

The majority of the warranty information and background data was collected through an extensive literature review. A considerable amount of information is available on the reliability improvement warranty, but it is dated. Little information or analysis is available on other warranty types. The literature search included a computer data base search and a review of all related material located at the Defense Logistics Studies Information Exchange. Other warranty information and background data were gleaned from personal and telephone interviews with legal, financial, and warranty administration executives from the Lockheed California Company, Douglas Aircraft Company of McDonnell Douglas Corporation, and General Dynamics Pomona Division.

E. DEFINITIONS

The following definitions shall apply for purposes of this thesis and are included to provide a clear understanding of terms.

1. Commercial Aviation Manufacturers: The commercial aircraft industry is comprised primarily of the Boeing Company and McDonnell Douglas Corporation. To a lesser extent, Lockheed Corporation has also been a key player, although now only in a fleet support role for the out of production L-1011 aircraft. U.S. manufactured aircraft account for 85.3 percent of jet powered transports and 67.6 percent of the total world turbine engine aircraft fleet. [2:15-16]
2. Warranty: The principal purpose of a warranty in a government contract is (1) to delineate the rights and obligations of the contractor and the government for defective items and services and (2) to foster quality performance. Generally, a warranty should provide (1) a

contractual right for the correction of defects notwithstanding any other requirement of the contract pertaining to acceptance of the supplies or services by the Government, and (2) for a stated period of time or use, or the occurrence of a specified event, after acceptance by the Government to assert a contractual right for the correction of defects. The benefits to be derived from a warranty must be commensurate with the cost of the warranty to the Government. [3:46.702]

3. Guarantee: For purposes of this thesis, the term guarantee is assumed to be synonymous to the definition of a warranty. The two terms will be used interchangeably.
4. Warranty cost: Warranty costs arise from the contractors' charge for accepting the deferred liability created by the warranty and Government administration and enforcement of the warranty. [3:46.703b]
5. Service and Warranty Costs: Service and warranty costs include those arising from fulfillment of any contractual obligation of a contractor to provide services such as installation, training, correcting deficiencies in the products replacing defective parts, and making refunds in the case of inadequate performance. When not inconsistent with the terms of the contract, such service and warranty costs are allowable. However, care should be exercised to avoid duplication of the allowance as an element of both estimated product cost and risk. [3:31.205-39]
6. Weapon System: The term will be defined as an item that can be used directly by the armed forces to carry out combat missions and that costs more than \$100,000 or for which the eventual total procurement cost is more than \$10,000,000. Such term does not include commercial items sold in substantial quantities to the general public. [4:2403]
7. Uniform Commercial Code (UCC): The UCC, based on common law, specifies the rights and obligations of the parties to a commercial transaction on the basis of fairness and reasonableness, in light of accepted business practice. The UCC is designed to simplify, clarify, and modernize the law governing commercial transactions. [2:48]
8. Reliability: The probability that an item will perform its intended function for a specified interval under stated conditions. [5]

9. Maintainability: A characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources. [5]

F. THESIS ORGANIZATION

Chapter II describes the history and legislative development of warranties in the Department of Defense. Chapter III focuses on specific warranty types such as the reliability improvement warranty, the mean time between failure warranty, and several standard commercial warranties. Chapter IV identifies the various costs and risks associated with warranty usage. Costs and risks are described for both the Government and the contractor. Chapter V is a presentation of several warranty pricing models. The models are analytic in nature, but the last section in the chapter addresses some nonanalytic pricing suggestions. Chapter VI, the final chapter, offers conclusions and recommendations for action and further study.

II. WARRANTY HISTORY AND LEGISLATION

A. INTRODUCTION

This chapter provides the reader with background on how the warranty concept was developed and what impact Congressional action has had on the use of warranties within the Department of Defense. Warranty history will be presented first, followed by a brief description of the current Congressional oversight process. Finally, a short section discussing the 1984 and 1985 laws will be offered.

B. WARRANTY HISTORY

For many years business operated on the principle of the buyer beware. Simply stated, this means there were no warranties, either implied or express, included with the purchase of durable goods. It was the responsibility of the buyer to determine product quality, reliability and performance characteristics. The buyer needed to make these decisions based on his own best judgement and at his own risk. If the product failed to perform as advertised or just plain failed to perform at all, there was little if any recourse available to the buyer. [2:78]

In 1938 the National Conference of Commissioners on Uniform State Law and the American Law Institute started an initiative to develop and disseminate a rather comprehensive act known as the Uniform Commercial Code. This act covers the aggregate field of commercial transactions. Although there were a number of revisions and changes to the act, it was published in 1957 and again in 1962 as the "1962 Official Edition." The Uniform Commercial Code was the first attempt to thrust some portion of the

responsibility for commercial transactions toward the seller. The Code defines the rights and obligations of the buyer and the seller in commercial transactions and provides definitions of warranties. [2:48]

In the Department of Defense there was very little use of any type of warranty prior to 1965 [6:4]. The Government up to that time had assumed the risk and cost associated with not having a warranty and seemed content with the concept of being a self-insured entity. The inspection clause that is normally included in each contract provided only limited protection to the Government, especially since inspections usually can not identify equipment performance deficiencies. Therefore, once an item was accepted by the Government, contractor liability was terminated.

As the technology and complexity of equipment and weapons systems increased, it became apparent that some form of contractor guarantee was needed that would ensure that the system do what it was designed to. In 1965, the Armed Services Procurement Regulation provided for the use of warranties [6:4]. This spawned the development and use in 1967 of the reliability improvement warranty which is discussed in detail in the following chapter.

Coincidentally, in 1965 consumer goods were receiving in-depth scrutiny from Ralph Nader who, through intensive investigation, had discovered serious design flaws in the automobile manufacturing process. His efforts helped focus public attention on the idea that the manufacturers have a moral and legal responsibility to produce products that would meet the expectations of the marketplace. As a result of the increased public attention, the warranty has come to serve as a legal tool to resolve the issue of

consumers' and manufacturers' rights and has been instrumental in developing and enforcing quality standards. [7:45-46]

Over the last twenty years, the use of warranties has increased and has become commonplace for purchases of consumer durable products. Although consumer products warranties are considered warranties (since they do provide some level of insurance against premature product failure), they must also be recognized as express statements which limit manufacturers' liability because coverage is usually for a very brief period and does not generally cover such things as performance or design.

While the consumer marketplace has seen an extensive increase in the use of warranties, the Department of Defense, on the other hand, has not made warranties a major contract issue except for occasional use in a few past aircraft procurements. Warranty coverage was simply not a matter of significance in the source selection process until the inception of the present Congressional attention. [7:47]

C. CONGRESSIONAL INVOLVEMENT

The American public, the House of Representatives, the Senate, and the President of the United States have all expressed concern over the increasing national debt. Additionally, public interest seems to be aroused by the news media's attention to the occasional ineptness of the Department of Defense and defense contractors in the procurement process. Such incidents exacerbate the public's perception of defense mismanagement. As a result, Congress has become more involved in the management of individual programs over the last ten years. The primary emphasis has been to spend the fewest dollars possible and still receive desired effectiveness and efficiency.

When public emotion is sufficiently aroused to create pressure on elected Congressional representatives, adequate impetus is provided to motivate intervention and encourage legislative action. While the level of federal spending for human services has increased from a very small proportion of defense spending to over double the present Department of Defense spending level, the perception pervades that defense spending is detracting from the Government's ability to provide human services programs. It is this emotional stigma that seems to be the motive focusing Congressional interest in warranty legislation, and it has resulted in a mandate that the Department of Defense will "get its monies worth." [7:54]

D. WARRANTY LEGISLATION

Following the introduction of the reliability improvement warranty in 1978 the Air Force Systems Command directed the expanded use of warranties in Air Force weapons procurements. Specific procurements included the Advanced Medium Range Air-to-Air Missile and various jet fighter engines. The Air Force, in conjunction with industry representatives, developed a Product Performance Agreement Guide and the Product Performance Agreement Center in an effort to establish an industry/DoD wide product performance and data analysis clearinghouse. [7:61]

In January 1981, the U.S. Army published AR 702-13 to establish requirements and procedures for use with the Army's warranty programs, but the regulation was apparently not very well promulgated nor was it comprehensively used [7:61]. Since 1981, the Department of Defense Acquisition Improvement Program has directed increased emphasis on the various incentives to improve reliability and support [8:9]. In 1983, Congress placed specific language in the Department of Defense Appropriations Act which

required warranties to be purchased as a part of any new weapons system acquisition unless a waiver is approved [8:9]. In 1984, the language was modified for the 1985 Appropriations Act which subsequently relaxed some of the earlier requirements of the 1984 act.

1. The 1984 Act

The 1984 Department of Defense Appropriations Act, Section 794 became effective on March 14, 1984. The act required that all Department of Defense fixed-price production contracts for weapons systems and/or significant components would contain a warranty provision.

There were two distinct warranty types covered by the act, both of which would be included in the contract: (1) the warranty would cover the weapon system and all major components and guarantee that each was designed and manufactured in conformance with government specified performance requirements and (2) the weapon system and each significant component shall be free from defects in material and workmanship at the time of delivery. [9:6]

Under the 1984 act, the contractor is required to bear all the costs of work for repair or replacement of parts that are necessary to attain the specified performance requirement. If the contractor fails to promptly repair or replace the required items, the contractor may be assessed to reimburse the Government for any costs incurred by the Government while making such necessary repairs through another source. [9:6]

The 1984 act specifically deletes the requirement for a warranty under cost-type contracts. Also, the warranty requirement is mandatory for prime contractors, but not necessarily for subcontractors. Section 794 requires guarantees from "the prime contractor or other contractors for such

(a weapon) system." The DoD Guidance [10] defines "procurement" as a prime contract, thusly allowing for the exclusion of a mandatory warranty on subcontractors.

A weapon system is defined in the 1984 act as "Equipment which, without substantial modification, is or can be used by the armed forces to carry out combat missions." [9:6]

The 1984 act has the provision for the waiver of the warranty requirement if it is in the interest of national defense and if the warranty is not cost effective. [9:6]

2. The 1985 Act

None of the affected parties, i.e. DoD, Congress, or industry, were happy with the original legislation. The 1985 act was passed essentially as a reform to the 1984 legislation. Some of the changes and modifications are discussed in this section.

The first noted alteration included a change in the definition of a weapon system. (See Definition 6, Chapter I for 1985 language.)

Of note also is the fact that the 1985 act required warranties that cover the weapon system to conform to design and manufacturing requirements. Additionally, the weapon system will be free from defects in materials and workmanship at the time of delivery to the Government, and if not, the prime contractor shall take whatever action is necessary to correct any deficiency at no additional cost to the Government. Failure of the prime contractor to make timely corrective action can cause the contractor to pay the Government for costs incurred. The Secretary of Defense is empowered to reduce the price of the contract to collect the cost of corrective actions

[11:13]. Any reference to other contractors i.e. subcontractors, has been removed from the 1985 act [9:6].

Interestingly, the 1985 revision does not automatically exclude cost-type contracts. Warranties are mandatory unless a waiver is authorized. Warranties will be included in cost-type contracts, but are applied only to the production of a weapon system. [11:13]

Under the 1985 act, the cost of a warranty may be included in the procurement price or may be priced as a separate line item. Language was added so that negotiation of specific warranty details could be accomplished. Such items include reasonable exclusions, limitations, and duration of the warranty. [11:13]

The 1985 Act was necessary to allow a reasonable avenue of approach that heretofore was not present in the 1984 legislation. The 1984 act seems to have been hastily passed without sufficient hearings or thorough development of terms, conditions, and requirements. It was quickly recognized that a modification was required to the 1984 act, and the passage of the 1985 act helped narrow some of the major differences that had developed between industry and the Department of Defense. While there are still a number of issues to be resolved between the Government and the contractors, the 1985 act allows for flexibility in the tailoring of warranty coverage.

E. SUMMARY

The use of warranties is not new. Some form of warranty has been used in commercial/consumer transactions for at least thirty years. While the Department of Defense has attempted on several occasions to use

warranties since the mid 1960's, no real sustained warranty program was maintained or universally applied.

Public awareness is now focused on perceived Governmental inefficiencies and this attention seems to have been the cause of the passage of the 1984 and 1985 legislation. Clearly, the defense establishment is going to have to learn how to adapt and price warranties as their usage is no longer voluntary in weapon systems acquisitions.

III. TYPES OF WARRANTIES IN USE

A. INTRODUCTION

The use and understanding of warranties are increasingly difficult issues. There is an unlimited number of variations that may be used to cause one type of warranty to differ from another. This chapter will focus on the warranties that are most commonly used by the aviation industry, but will briefly discuss the characteristics of warranty types; that is, implied and express warranties.

B. IMPLIED WARRANTIES

Implied warranties according to Ruben [12:40] are read into contracts by common law, even if the specific language is not addressed. The protection given under implied warranties is in the provisions of merchantability, usage of trade, and fitness for purpose. The Uniform Commercial Code definition [13:125] of an implied warranty is as follows:

Implied Warranty: Merchantability: Usage of Trade (UCC 2-314)

(1) Unless excluded or modified (Section 2-316), a warranty that the goods shall be merchantable is implied in a contract for their sale if the seller is a merchant with respect to goods of that kind. Under this section the serving of food or drink to be consumed either on the premises or elsewhere is a sale.

(2) Goods to be merchantable must be at least such as:

- (a) pass without objection in the trade under the contract description; and
- (b) in the case of fungible goods, are of fair average quality within the description; and
- (c) are fit for the ordinary purposes for which such goods are used; and

(d) run, within the variations permitted by the agreement, of even kind, quality and quantity within each unit and among all units involved; and

(e) are adequately contained, packaged, and labeled as the agreement may require; and

(f) conform to the promises or affirmations of fact made on the container or label if any [14:865].

Implied Warranty: Fitness for Particular Purpose (UCC 2-315)

Where the seller at the time of contracting has reason to know any particular purpose for which the goods are required and that the buyer is relying on the seller's skill or judgment to select or furnish suitable goods, there is unless excluded or modified under the next section an implied warranty that the goods shall be fit for such purpose [14:865].

Although implied warranties provide protection to the buyer, an implied warranty may be specifically excluded by calling the buyer's attention, in understandable language, to the fact that warranties are excluded and that there is no implied warranty. In addition, an implied warranty is excluded when a buyer has examined the goods, sample, or model as fully as he wanted to (prior to entering into the contract) or he has refused to examine the goods. [14:865]

The benefits and limitations of an implied warranty should be fully understood by the buyer. A violation of an implied warranty as defined by the Uniform Commercial Code can cause a seller to be liable for restitution to the buyer. Other liabilities not covered explicitly and not defined by common law or the Uniform Commercial Code should not be construed to constitute an implied warranty.

C. EXPRESS WARRANTIES

The express warranty is defined in the Uniform Commercial Code section 2-313 as follows:

(1) Express warranties by the seller are created as follows:

(a) Any affirmation of fact or promise made by the seller to the buyer which relates to the goods and becomes part of the basis of the bargain creates an express warranty that the goods shall conform to the affirmation or promise.

(b) Any description of the goods which is made part of the basis of the bargain creates an express warranty that the goods shall conform to the description.

(c) Any sample or model which is made part of the basis of the bargain creates an express warranty that the whole of the goods shall conform to the sample or model.

(2) It is not necessary to the creation of an express warranty that the seller use formal words such as "warranty" or "guarantee" or that he have specific intention to make a warranty, but an affirmation merely of the value of the goods or a statement purporting to be merely the seller's opinion or commendation of the goods does not create a warranty. [14:865]

In general terms, the express warranty represents the seller's assurance that his equipment, parts or other goods are free from defects in material, workmanship, and design for a specific period of time. Design is a special case somewhat unique to the Government and will be discussed in more detail later in the chapter.

Black's Law Dictionary [15:1423] further defines the warranty as:

A warranty is a statement or representation made by a seller of goods, contemporaneously with and as a part of a contract of sale, though collateral to express object of sale, having reference to character, quality, or title of goods, and by which seller promises or undertakes to insure that certain facts are or shall be as he then represents them.

A warranty is a written statement arising out of a sale to the consumer of a consumer good pursuant to which the manufacturer, distributor, or retailer undertakes to preserve or maintain the utility or performance of the consumer good or provide compensation if there is a failure in utility or performance; or in the event of any sample or model, that the whole of the goods conforms to such sample or model. [15:1423]

In most cases, the express warranty is the preferred warranty type. It offers very specific protection to the buyer against premature failure, defect, or misrepresentation over a specified period of time. The express warranty, by being offered either orally or in writing, can become an instrument of the courts and therefore, has the power and effect of law behind it.

There are other benefits, however. The greatest apparent benefit attending the inclusion of warranties in contractual clauses is strictly a financial one. The warranty can provide for the repair or replacement of defective items or compensate the buyer during the period of coverage. This can be either prorated through the useable life remaining in the product, or it may be a free replacement or repair. [7:15-16] As is the case with the standard commercial warranty, Chrysler Corporation's 5 year/50,000 mile vehicle warranty for example, the costs of parts and repair labor are essentially free to the buyer. The term "free" needs further definition at this point. The replacement of parts and expenditure of labor is "free" to the buyer from the aspect of no additional charge for the warranted defect. The buyer, however, should be thoroughly aware that the warranty costs are in fact not "free", but implicitly charged in the initial purchase price of the vehicle.

The remainder of this chapter and indeed, the thesis as a whole, will deal specifically with the various forms of express warranties. The previous section on implied warranties is presented to aid the reader's understanding and awareness of the two major categories of warranties and to complete the spectrum of the research effort.

D. WARRANTIES IN USE

1. The Reliability Improvement Warranty

The reliability improvement warranty has developed as a result of many years of trial, error, and modification. The basic purpose of the reliability improvement warranty is to force contractors to share some measure of the risk in the development and sale of equipment that historically has demonstrated high failure rates.

The reliability improvement warranty had its origin in 1960. The Air Force Logistics Command in 1960 was tasked to study a concept called the Real/Ultimate Cost of procurement. The study was expanded to include a product-life warranty system. The results of the study lead to the identification of a piece of equipment for which improved reliability was severely needed. The Instrument Division of Lear Siegler, Inc., offered to participate in the development, through a planned multi-year procurement starting in 1965, for several thousand MD-1 vertical gyroscopes. Lear Siegler agreed to participate in the development of the "failure free warranty", which was ultimately called the reliability improvement warranty, on the basis of repairing or replacing, at their option, any unit that failed within five years or 5000 operating hours, whichever occurred first. This initial offer was never accepted by the Government. However, in 1967, the Navy did award Lear Siegler the first failure free warranty contract for the overhaul and repair of 800 displacement type gyroscopes. The contract called for the increase of the mean time between failure from the 400 hour baseline to 520 hours by December 1972. Actual progress resulted in an achieved 531 hours mean time between failure by January 1973. As a follow on, the Air Force

awarded Lear Siegler a similar contract which was competitively awarded, to produce an avionics system for the F-111 aircraft. [16:7-9]

After the early successes with the initial Lear Siegler contracts, it became clear that the old way of doing business, i.e. the contractor's liability ceased once the equipment was accepted by the Government, was no longer the most advantageous to the Government. Under the then existing procurement practices, it was difficult, if not impossible, to motivate the contractor to improve reliability since there was no requirement to continue the relationship after the initial procurement contract was fulfilled. The reliability improvement warranty on the other hand, incentivises the contractor to improve the reliability of the product since the contractor (1) will be required to effect repairs at a fixed fee for periods of two to five years after initial delivery and (2) will improve profit margin, up to a ceiling, by bettering the mean time between failure rate (ergo reducing maintenance costs), with the difference in dollars spent realized as additional profit. Because the contractor now has a vested interest in the reliability of the product, it becomes paramount that the contractor develop tracking and recording techniques to monitor use, performance, reliability, maintainability, and other information that heretofore has been of little concern because liability was limited only up to the time of Government acceptance. The contractor's collection and use of this new information should impel design reviews and retrofit, resulting in a more reliable product, increased profit for the contractor and lower life cycle cost for the Government.

Furthermore, the continuous contact between the Government and the contractor can provide considerable market advantage for future procurement needs. The contractor may be able to obtain knowledge of other

Department of Defense requirements and therefore, have a competitive edge during the competitive bidding process. [7:41]

It should be also noted that the reliability improvement warranty was not designed to be a maintenance contract. In fact, the routine maintenance and upkeep of the equipment is the responsibility of the buyer unless otherwise specified by contract. [6:6]

If, during the course of the warranty period, the contractor discovers that a design change or equipment change will improve the reliability of the system and result in a reduced number of future repair actions, a no-cost-to-the Government Engineering Change Proposal (ECP) may be submitted. If the change proposal is approved, the design change is authorized. The contractor's profit from the design change is realized only by the reduction in the number of required repairs occurring during the warranty period. [17:222]

The Reliability Improvement Warranty Guidelines, enclosure to ASD/I&L to Service Assistant Secretaries dated 14 August 1974 [18:5], set forth the parameters that are to be considered in determining equipment as candidates for the reliability improvement warranty. Specifically, they are as follows:

- (a) A warranty can be obtained at a price commensurate with the contemplated value of warranty work to be completed.
- (b) Moderate to high initial support costs are involved.
- (c) The equipment is readily transportable to permit return to the vendor's plant or, alternatively, the equipment is one for which a contractor can provide field service.
- (d) The equipment is generally self contained, is generally immune from failures induced by outside units, and has readily identifiable failure characteristics.

(e) The equipment application in terms of expected operation time and the use environment are known.

(f) The equipment is susceptible to being contracted for on a fixed price basis.

(g) The contract can be structured to provide a warranty period of several years. This should allow the contractor sufficient time to identify and analyze failures in order to permit reliability and maintainability improvements.

(h) The equipment has a potential for both reliability growth and reduction in repair costs.

(i) Potential contractors indicate a cooperative attitude toward acceptance of an RIW provision and evaluation of its effectiveness.

(j) A sufficient quantity of the equipment is to be procured in order to make the RIW cost effective.

(k) The equipment is of a configuration that discourages unauthorized field repair, preferably sealed and capable of containing an Elapsed Time Indicator (ETI) or some other means of usage control.

(l) There is a reasonable degree of assurance that there will be a high utilization of the equipment.

(m) The equipment is one that permits the contractor to effect no-cost ECPs subsequent to the Government's approval.

(n) Failure data and the intended operational use data can be furnished the contractor for the proposed contractual period and updated periodically during the term of the contract.

These are the guidelines that were mandated, although it should be noted that each and every one of the listed recommendations does not have to be met in order for an equipment to be eligible for coverage under a reliability improvement warranty. [16:20]

Finally, there are several key points to consider when attempting to use and evaluate the reliability improvement warranty. First, there is the

potential for the contractor to understate the initial mean time between failure operating levels so that the opportunity exists for definite "shown" reliability improvement at some point later in the contract [5:42]. Second, because each piece of equipment is different in operating characteristics and inherent failure rates, the use of a "standard" reliability improvement warranty clause for each contract is not suggested. Instead, every potential reliability improvement warranty contract must be evaluated on its own merit. The reliability improvement warranty clause should include items such as length of warranty, the definition of a failure, purpose of the warranty, the cost of shipping failed goods to the contractor and who pays for it, repair turn around time, who maintains records for each unit under warranty, and any other special circumstance that is peculiar to that type of equipment. [6:7]

2. The Mean Time Between Failure Warranty

The mean time between failure warranty is actually a subset of the reliability improvement warranty. Under the provisions of the mean time between failure warranty, a manufacturer guarantees that the equipment will operate/perform equal to or exceeding some agreed upon mean time between failure baseline. In the situation where it falls short of the established baseline, the manufacturer must institute corrective action at his expense until the mean time between failure improves to meet the previously agreed level. [17:222]

Additional requirements for contractor resolution/support may also be used in the mean time between failure warranty. An example is cited in the Air Force F-16 procurement contract.

Two of nine line replacement units (LRUs) are also covered by an MTBF guarantee. In addition to requiring the contractor to repair or replace failed units, the MTBF guarantee requires him to provide corrective action as well as additional spares if units fail to meet the mean time between failure specified in the contract. The actual number of spare units to be provided must be calculated from a formula contained in the RIW contract. If the value of MTBF that is guaranteed to be achieved by the final year of the RIW is achieved prior to that time, as demonstrated by two consecutive measurement periods, then the contractor is released from any further obligations under the MTBF guarantee. The LRUs will, however, remain under the RIW. [19:4-2]

Note the very fine distinction between the reliability improvement warranty and the mean time between failure warranty. The reliability improvement warranty typically establishes a baseline mean time between failure and attempts to provide sufficient incentive, such as additional profit, to induce the contractor to increase product reliability to a higher mean time between failure level. Attainment of that goal is not mandatory nor is it guaranteed. In comparison, the mean time between failure warranty establishes a baseline mean time between failure very similar to the reliability improvement warranty, but in this case, the contractor must guarantee achievement of performance to the agreed level.

Because the mean time between failure warranty establishes "must meet" requirements, the very first unit off the production line has to be capable of performing to the required mean time between failure baseline. Consequently, the higher-than-usual initial performance criteria may tend to drive up the cost of the warranty and therefore, should be used primarily where high readiness is mandatory.

3. The Mean Time to Repair Warranty

Like the mean time between failure warranty, the mean time to repair warranty has historically been used as an option included with the reliability improvement warranty contract. Simply stated, it establishes a time period by which the contractor is required to perform repair work on a defective piece of equipment and return it to operational condition [7:43].

The Air Force F-16 reliability improvement warranty included repair turnaround time requirements. Average turnaround time was computed in six month intervals. Repairs, replacement, and modifications were required to be completed within 22 days. If the contractor failed to meet the deadline, additional units were to be loaned to the Air Force. Failure to provide the loan units could result in a dollar penalty. [17:225]

Even though the mean time to repair warranty is usually used in conjunction with the reliability improvement warranty, it does not add to the improvement of equipment reliability [7:43]. This type of warranty is a tool to insure that the contractor performs warranted repairs in an expedient fashion so as to reduce the amount of downtime on vital major systems.

4. The Non-Warranty Warranty

The non-warranty warranty is the researcher's reference to a consumer products warranty. The purpose of this discussion is to differentiate between the consumer products warranty and the standard commercial aviation warranty type which will be examined in the following section.

Consumer goods warranties have actually had a very poor record over the years. This type of warranty has generally been used as an enticement to improve product sales or, and this is key, to limit the seller's liability through inclusion of specific disclaimers or exclusions.

The automobile industry warranties provide an excellent example of the non-warranty warranty principle.

Prior to 1960 all automobile manufacturers were providing a three month or 4,000 miles warranty to consumers and a concealed one year or 12,000 miles warranty to dealers [20:35-36].

In an effort to increase sales, Ford Motor Company decided to transfer the hidden one year or 12,000 miles warranty directly to the customer. The other major car manufacturers, recognizing the threat to their sales position, followed suit and matched their warranties to that of Ford. [20:36]

In 1962, Chrysler Corporation initiated the 5 years or 50,000 miles warranty which covered power and drive train. The other manufacturers elected not to match Chrysler's offer, but instead elected to offer two year warranties for the entire automobile. This dissimilarity remained in effect until 1967 and is believed to have been the primary factor in improving Chrysler's market share by 67.7 percent, doubling sales volume and tripling net income. [20:36]

In 1967 all automobile manufacturers, seeing the apparent benefits gained by Chrysler, matched the 5 year or 50,000 mile warranty which remained intact until it was abandoned in 1971,

... because they were too expensive. In those days, our cars weren't really good enough to back them for half a decade [21:148].

Mr. Iococca appears to have been correct. The Federal Trade Commission's Report on Automobile Warranties in 1968 concluded that:

1. Quality control and warranty performance were declining.
2. The industry deliberately oversold its improved warranty in the 1960s, creating the impression that "higher levels of engineering and manufacturing skill" had overcome the complexity of the automobile.

3. Warranty extensions had no correlation with quality or developments in engineering or manufacturing.

4. The industry ran one ad after another emphasizing the warranty as proof of a better made car. [20:36]

As was previously mentioned, the consumer products warranty can also act as a limitation on seller's liability. In the House Interstate and Foreign Commerce Committee's Staff Report on Consumer Products Warranties [22], it was found that numerous exemptions and disclaimers were used that specifically limited producer's liability rather than protecting the buyer. The report listed some of the more common disclaimers as follows:

1. Transportation and shipping costs and/or serviceman's travel charges excluded.
2. Home use only--other uses excluded.
3. Filters, plastic, and/or glass parts excluded.
4. Consequential damages excluded.
5. Disclaimer of implied and all other warranties.
6. Limited to parts or specific parts only.
7. Warranty registration card required.
8. Void if serial plate defaced.
9. Special appliances excluded.
10. Opinion of seller governs.
11. Valid for original purchaser only. [20:37-38]

Although the Federal Trade Commission has been tasked by Congress to monitor warranty protection to the consumer, the non-warranty warranty is still used extensively. The five years or 50,000 miles warranty has been reinstituted by Chrysler Corporation on all of its vehicles. Mr. Iococca says,

"we build them better and we back them better", but on further examination the warranty covers material and workmanship only. Original Chrysler spares and repairs are required to keep the warranty valid, and the cost effectiveness is unknown to the buyer since the warranty cost is an integral part of the purchase price.

Under the 1985 warranty law mandated by Congress and described in the previous chapter, a warranty has three distinct parts. First, a warranty must cover material and workmanship. The Chrysler warranty does. Second, a warranty must cover performance requirements. The Chrysler warranty does not. Third, design and manufacturing requirements are to be warranted. Again, Chrysler does not. The 1985 Defense Authorization Act also allows waiver of warranty if it is not cost effective. The Chrysler warranty is not a "delete for credit" cost option. Clearly, the commercial warranty does not meet the Congressional definition of a warranty. Defense contractors have "to back them better."

5. The Standard Commercial Aviation Warranty

The standard commercial warranty, like most consumer warranties, seems to have been developed as an instrument of competition. Aircraft manufacturers, seeking increased sales and larger market shares, introduced the warranty as a marketing tool. Seemingly, the manufacturer offering the most attractive warranty, all other factors being nearly equal, may capture a larger portion of available customers.

Again, like the consumer protection warranty, the standard commercial aviation warranty operates as a manufacturer's limit of liability. The warranty may be considered a customer protection plan, but as the

commercial warranty is written, it also serves very heavily as a protective measure for the manufacturer.

The warranty can also provide the manufacturer with a form of feed-back such that the field reliability of the product, as well as apparent design weaknesses, can be improved and further increase marketability of the aircraft. Both the military and the commercial aircraft industry are vitally interested in field reliability and life cycle costs, albeit for reputedly different reasons. The military is concerned primarily with operational readiness and mission effectiveness, although concern over budgetary limitations is fast becoming a major issue as well. The commercial aircraft industry's motivation is much simpler; that is economic survival.

The most prevalent commercial aircraft warranty is the "failure free" warranty which covers equipment during a specified period of time and provides for repair of failed items by the manufacturer, or seller if not one in the same, or for cost reimbursement to the airline for the repair work performed during the warranty period. This warranty often includes a guaranteed turn around time similar to the reliability improvement warranty discussed earlier. Of special note, almost every standard commercial aviation warranty includes a disclaimer and exclusion of any other implied or express warranties, which not coincidentally, meets the requirement of the Uniform Commercial Code. Standard commercial aviation warranties typically have been in force for a one year period, although longer periods of up to three years have been noted on newer aircraft systems [16:13].

Because the commercial warranty covers aircraft performance rather than specific end use, a commercial buyer historically has received a longer, more extensive warranty than has the military. An exception to that

trend will be explored in the next section on the Air Force KC-10 aircraft.

[23:14]

Examples of commercial aviation warranties are summarized below:

1. Lockheed-California Company: Lockheed Corporation manufactured the now defunct Lockheed L-1011 aircraft for the commercial market. The warranty provided an 18 month period to cover design-related defects on the airframe. Material and workmanship were covered for a two year period after delivery of each aircraft. A service life contract was provided with each aircraft and provided protection for 12 years from the date of delivery with no limitations on flight hours or number of landings. The service life contract covered primary structural elements of the wing, fuselage, vertical fin, horizontal stabilizer, pylons, main landing gear, and the nose landing gear. Note that there is no engine warranty except as what may be offered separately by the engine manufacturer.

Lockheed's warranties as set forth in paragraph (a) hereof are exclusive, are in lieu of, and buyer hereby waives, all other warranties, express or implied, including without limitation, any implied warranties of merchantability or of fitness. [See Appendix A for actual warranty].

2. The Boeing Company: The Boeing Aircraft Company manufactures the Boeing 727/737/747 models primarily for the commercial airline industry. These three aircraft are warranted to be free from defects in material and workmanship for a period of 24 months after delivery of the aircraft. However, if a defect in material or workmanship is discovered in an accessory, equipment, or part which was installed in an aircraft at the time of delivery and which has not been inspected by

the buyer under the buyer's approved maintenance program prior to the expiration of the above period, the warranty period as to such defect shall be extended to the first to occur of the following:

... completion of the first inspection applicable to such item under the buyer's approved maintenance program following expiration of the above period, or

... expiration of 36 months after delivery of such aircraft.

Defects in design are covered for 18 months after delivery of the defective aircraft, accessory, equipment or part.

The Boeing Company also offers a service life policy. This policy covers any covered component that fails within 10 years of delivery of the aircraft on which it was installed. Like the Lockheed service contract, the Boeing offer also covers any airframe component or landing gear component, but it is not free. Price for such service is established in the contract. The Boeing Company does not itself offer an engine warranty, but is authorized to extend to the buyer the provisions of the engine manufacturer's warranty. Also note the warranty limitations as follows:

... The warranties, obligations and liabilities of Boeing and remedies of the buyer set forth in this part A are exclusive and in substitution for, and buyer hereby waives, releases and renounces all other warranties, obligations and liabilities of Boeing and any assignee of Boeing, express or implied, arising by law or otherwise, with respect to any nonconformance or defect in any aircraft or other thing delivered under this agreement, including but not limited to (A) any implied warranty of merchantability or fitness, (B) any implied warranty arising from course of performance, course of dealing or usage of trade, (C) any obligation, liability, right, claim or remedy in tort, whether or not arising from the negligence of Boeing or any assignee of Boeing, actual or imputed, and (D) any obligation, liability, right, claim or remedy for loss of or damage to any aircraft, for loss of use, revenue or profit with respect to any

aircraft, or for any other direct, incidental or consequential damages. [See Appendix B for the full Boeing Warranty provisions.]

3. McDonnell Douglas Corporation: McDonnell Douglas Corporation manufactures the DC-8/9/10 series aircraft and the MD-80 aircraft for the commercial airline market. The McDonnell Douglas Corporation warrants aircraft defects in material and workmanship and defects caused by installation by the seller of any article not manufactured by seller in a manner not in accordance with the reasonable instructions of the manufacturer; defects arising from failure to conform to the Detail Specification (Exhibit "A" of the purchase agreement), except as to portions so stated to be estimates, approximations, or stated to be design objectives, for a period of twenty-four months after the delivery of each product. As with the Boeing Company, McDonnell Douglas Corporation will warrant defects in material and workmanship for a period of up to thirty-six months or until the buyer's established maintenance program has had full opportunity to inspect, whichever shall first expire after delivery of each product.

Defects inherent in the design, including defects arising from selection by the seller of materials or process of manufacture, in view of the state of the art as of the date of such design, are covered for a period of eighteen months within delivery.

McDonnell Douglas Corporation, as do the other commercial aircraft manufacturers, has a service life policy. The policy states that should a failure occur in any covered component of an aircraft within ten years after delivery to the buyer regardless of the number of flight hours or cycles, the seller will, at the price provided and as promptly

as practicable, design and furnish to the buyer a correction for such failed component and provide any parts required for such correction.

Like the previous two warranties McDonnell Douglas Corporation also includes exclusion statements

The warranty and service life policy provided in this part I. and the obligations and liabilities of seller under said warranty and service life policy are exclusive and in lieu of, and buyer hereby waives, all other remedies, warranties, guarantees or liabilities, express or implied, with respect to each aircraft, article, product, accessory, equipment, part, service, manual, document and data delivered under this agreement and related documents, arising by law or otherwise (including, without limitation, any obligation or liability arising from negligence or tort or with respect to fitness, merchantability, loss of use, revenue or profit or consequential damages). This warranty or service life policy shall not be extended, altered or varied, except by a written instrument signed by seller and buyer.

Buyer and seller state and agree that this part I. has been the subject of discussion and negotiation and is fully understood by the parties and that the price of the aircraft and the other mutual agreements of the parties set forth in this agreement were arrived at in consideration of the provisions of this part I., specifically including the waiver by buyer set forth in paragraph D.1. above. [See Appendix C.]

Comparisons of all three of the above standard commercial warranties reveal very few differences. The Lockheed Company's service life policy runs for 12 years versus 10 years for Boeing and McDonnell Douglas. All other aspects of the warranties, including coverage for design, materials and workmanship, are the same except for minor wording changes in the disclaimer and release clauses. Due to the nearly indistinguishable nature of these warranties, any perceived benefit, i.e. the benefit in choosing one company's aircraft over another resulting from better warranty inclusion in a purchase agreement, is nullified. It seems a moot point, but the

similarity of the warranties would appear to preclude any likelihood of one particular company having any noticeable market advantage over another.

6. The Commercial/Military Aviation Warranty

The commercial/military aviation warranty is an adaption of the standard commercial aviation warranty to reflect consideration for the military use of a commercial type aircraft. Since the commercial operating environment differs significantly from the military environment, aircraft are frequently different in design and performance [23:10]. Such is the case with the Air Force's KC-10 Extender Advanced Tanker Cargo Aircraft. This particular aircraft is about 80 percent DC-10 with 20 percent modification to meet the military mission requirement.

This contract is unique in that the Air Force decided to procure the KC-10 as the commercial market would, but additional emphasis was placed on warranty provisions to be included in the proposals.

The KC-10 program office obtained copies of the aircraft manufacturers standard warranty provisions and compared them to the correction of deficiencies clause contained in the contracts for major weapons systems [24:37].

Although the correction of deficiencies clause was preferred to the standard commercial warranty, it was not insisted on as an inclusion to the contract. Each competitor was to be afforded the opportunity to offer their best business deal to the Government in hopes that an included warranty would exceed the limitations of the standard clause. The decision to allow the use of the standard commercial warranty was based on four reasons:

1. The high cost of a correction of deficiencies clause.
2. The negligible cost savings of deletion of the standard warranty provision.

3. The apparent success the commercial airlines have had with the standard commercial warranty.
4. The existence of the option of passing on the responsibility for warranty administration to a competitively selected logistics support center. [24:37]

Douglas Aircraft Company of the McDonnell Douglas Corporation was ultimately awarded the contract, and the logistics support contract was included as a simultaneous award. The resultant contract was a standard commercial contract with a warranty which had been modified to reflect military usage.

Interestingly, several warranty improvements resulted from the process. Douglas Aircraft Company warranted spare and replacement parts [24:37]. Other warranty coverage was as follows:

Defects in material and workmanship and defects arising from the failure to conform to specifications must become apparent to the customer within 60 months or 5,000 flying hours, whichever comes first. In light of the relatively low utilization rate anticipated for the KC-10, the normal commercial warranty life of 24 months was expanded to 60 months; the number of flying hours remained the same.

Defects in design, including those arising from the contractor's selection of material or manufacturing process, were also warranted. These defects must become apparent to the customer within 24 months of delivery. Normally, coverage for these kinds of defects extends 18 months. No flying-hour limitation was tied to this category of warranted defects. [24:38]

As is the case with the standard commercial warranty, and that is nearly what the KC-10 warranty is, there are a number of exclusions to be noted. For example, if aircraft maintenance is not performed in accordance with the contractor's approved method, the warranty will be voided. Other things such as improper operation or performance of repairs without the

contractor's approval will also relieve the contractor of any liability.

[24:38]

The service life policy, again a characteristic of the commercial warranty, is included and provides coverage of selected components. The service life policy for airframe components is 30,000 flying hours or 10 years, whichever occurs first. Landing gear components are covered for 20,000 landings, 30,000 flying hours, or 10 years. [See appendix D for exact warranty coverage.]

This researcher has discovered numerous references to the noted success of the commercial aviation warranty. The Air Force's KC-10 program appears to have all the merits of the commercial warranty plus the benefits derived by uniquely allowing the warranty coverage to be tailored to the military operating environment.

7. The Military Aviation Warranty

The Department of Defense frequently has aircraft requirements for performance and design that do not fall within the auspices of the commercial aviation marketplace. When this happens, development programs are instituted. Such was the case for the Air Force's C-17 cargo aircraft.

The C-17 program was initiated because the Air Force felt there existed a critical shortage in airlift capability. This was especially true for oversized cargo such as infantry vehicles, artillery, and helicopters. Since there was no capable aircraft already commercially available, the Air Force released a request for proposal for development of such an aircraft. The McDonnell Douglas Corporation won the contract which was to perform limited research and development and included options for full scale engineering and production. [25:38]

The program failed to reach the production stage, but the program itself was useful in that it was targeted toward design to life cycle cost and not just design to production cost goal. The advantages of a design to life cycle cost goal instead of a design to production cost goal become evident at the front of the program because it forces the contractor to consider support costs via specified reliability and maintainability levels from the outset. It also causes the contractor to evaluate materials selection and design choice carefully since the contractor's profit for initial spares and repairs can be reduced if he fails to achieve reasonable support cost goals. Air Force concern over support costs was emphasized because support costs for several other cargo aircraft programs, specifically, the C-5 and 747 had averaged 180 percent of the acquisition costs. By designing to life cycle cost objectives, the contractor is inclined to consider the design trade-offs since they will certainly impact on the reliability and maintainability of the aircraft in future periods. [25:38-39]

In most of the other warranty types previously discussed, reliability and failure parameters were established as a subsystem of the major platform. The reliability improvement warranty for the Air Force's F-16 establishes the mean time between failure for line replacement units on various electronic components as an example [19:39]. The C-17 contract establishes the reliability and maintainability at the system level. There are several advantages to this approach. First it allows the manufacturer the flexibility to consider design trades and provide some degree of design freedom. Second, it drives the follow-on design of future support and maintenance equipment to be compatible with the system. [25:39]

The C-17 contract required a continual review and evaluation of the aircraft reliability and maintainability.

Depending upon the reliability, maintainability, and availability levels achieved, either a special warranty provision or an incentive provision will apply. If the contractor exceeds the threshold and reaches the goal established for a particular factor, an incentive provision takes effect. But if the contractor fails to satisfy any one system-level reliability, maintainability, or availability requirement, a warranty provision obligates him to provide no-cost corrective action.

The warranty covers the aircraft itself, equipments and support items, including technical orders, software, and data. Besides requiring no-cost corrective action, the warranty provision stipulates that if the contractor fails to meet any one system-level reliability, maintainability or availability threshold, he loses one half of any other reliability, maintainability, and availability incentives earned. [25:41]

In contrast to the warranty examined in the previous section, where the period of warranty coverage was up to 60 months, the C-17 warranty period was to be 180 days. However, with this warranty, the contractor must meet or exceed system specifications for 180 days after initial operational capability or the contractor must effect repair, rework, or redesign. Initial operational capability is defined as the delivery of 12 production configured aircraft, with all ancillary items required by the contract to perform the assigned mission. Each aircraft and its structures, subsystems, spares, support equipment, and software must be free from defect in design, materials, and workmanship for 180 days after delivery of the last aircraft. If a defect is found, the contractor must repair, rework, or redesign. Design information must be free from defect for 180 days from delivery of the data or the contractor must correct defects and repair any subsystem damage which resulted from use of the data.

The service life policy for the C-17 provides for a prorated price sharing of any airframe or landing gear defects. The airframe components are covered for a period of 10 years or 10,000 flight hours. The landing gear is covered for 10 years or 20,000 landings. [See Appendix E for exact warranty details.]

This application of contracting and warranty usage is quite a radical concept when compared to the standard commercial warranty. The shortened warranty period is most notable, but the extensive coverage of the full system in lieu of subsystems may result in considerable life cycle cost reductions to the government.

E. SUMMARY

Only a few of the warranty variations possible in the Department of Defense and commercial aviation procurement processes have been examined. The intent of this chapter is to highlight some of the more important details of the warranty types that have been used, so that understanding and realization of warranty ramifications can be employed to the best advantage in future procurements. Warranty issues are not going to disappear. The 1984 and 1985 warranty legislation approved by Congress will direct even greater emphasis toward warranty usage and effectiveness. Finally, it is important to realize that the warranty methods examined do not necessarily reflect what is the most economical nor efficient alternatives to the various aircraft contracts. The program manager must evaluate and use careful judgement in making that determination.

IV. WARRANTY COSTS AND RISKS

A. INTRODUCTION

Warranty costs are a major concern to both the Government and the prospective contractor. The inclusion of a warranty can have a significant effect on contract cost and contractor profit, especially if governed by the recent Congressional mandates. As demonstrated in the previous chapter, there are numerous types of warranties and seemingly an infinite number of variations possible within each warranty type. This chapter will address warranty costs in generic terms with the hope that better understanding of the cost issues by both Government procurement personnel and prospective contractors will drive better business deals for both parties and reduce adversarial relationships.

B. COST/RISK TRADEOFFS

To a contractor, risk translates simply to cost. As a general rule, when risk increases, cost of the contract will also increase. The contractor is in neither a financial position nor the business to assume unrewarded risk. It seems likely therefore, that the more warranty coverage required by the buyer, the more risk the contractor is being asked to assume and the greater the probability that, in the long run, those costs will be passed on to the buyer. The spectrum of cost/risk tradeoff can be carried to extremes. One party can absorb all of the costs and risks or the other party can absorb all of the costs and risks, but neither solution is usually equitable. Generally, marketplace negotiations force cost/risk sharing between the buyer and the

seller, although the sharing is not necessarily an equal split. This concept can be demonstrated by the following examples.

In the application of a reliability improvement warranty, assume the contractor is being tasked to improve or increase the reliability level of a new piece of equipment. Because there is little to no failure data available, the contractor is forced to assume a very high risk due to the inability to determine or accurately estimate either the failure rate or the amount of expense required to correct future deficiencies. Therefore, it would stand to reason that the risk would be converted to a "most likely" cost estimate, which would be included in the procurement price and result in higher overall cost. Recall that while a minimum threshold failure rate is established in the basic reliability improvement warranty, it does not usually penalize the contractor for failing to achieve that level. It merely attempts to incentivize the contractor to improve reliability through the instrument of potentially higher profits. However, because very high initial risk is anticipated by the contractor, warranty price may be very high in order to compensate the contractor for the perceived risk. The Government, on the other hand, desires product reliability and may pay unnecessarily high cost and still not receive much benefit of the included warranty. [26:59]

Introduction of a mean time between failure clause in a reliability improvement warranty tends to raise contractor risk even more. Inclusion of the mean time between failure guarantee will often be accompanied by penalty provisions such that if the contractor fails to achieve the specified mean time between failure level, corrective action must be initiated. Typically, these corrections would include the performance of engineering analysis to identify the cause of failure or substandard performance, submission

of engineering change proposals, modification of existing units, and provision of additional spares to the buyer on a loan basis until mean time between failure improves to the guaranteed level [26:44-45]. Inherently, every one of these provisions introduces added risk to the contractor, since each represents potential additional expense. It follows that because the buyer insists on stronger warranty requirements, which in turn raises contractor risk, the warranty coverage will be passed on to the buyer in the form of higher contract cost, either implicit or explicit.

Determining real warranty cost and price is a very delicate balancing game and the contractor must carefully evaluate warranty price versus risk. Competition in Department of Defense procurement actions is becoming more prevalent. As such, if the contractor in the bidding process submits too high a price, the contract will be awarded to a lower bidding competitor. If the contractor underestimates the risk factor and fails to charge sufficiently to recover costs and is therefore caused to render excessive repairs during the warranty period, a decrease in profit or even a loss can result [26:21].

The risk associated with the standard commercial warranty seems to be significantly less than with defense warranties for several reasons. First, commercial aircraft are sold to several customers instead of just one, which allows the production base to be larger and be spread out over a longer period of time. This helps reduce total risk, because greater numbers of aircraft will be sold and risk can be absorbed at a less apparent amount per aircraft. Second, as pointed out in the last chapter, standard commercial warranties specifically include disclaimers and releases of liability as conditions of express warranty coverage. Third, all implied warranties are

totally excluded from the standard commercial warranty which again reduces risk. Finally, commercial aircraft are used very heavily so usually little total time has to elapse before defects become evident. This allows the manufacturer the opportunity to make corrections early in the production run thus reducing the risk of costly redesign or retrofit after large numbers of aircraft have already been delivered to the customers.

Risks seem to be sufficiently low in the standard commercial warranty because every major aircraft manufacturer in the United States offers nearly the identical warranty to commercial customers at "no extra cost." This indicates that either the risk/cost factor has in fact been reduced to an acceptable level because of the broad production base, or these same manufacturers have decided that whatever inherent risk remains, it is necessary in order to remain competitive in the market.

C. COSTS AND RISKS TO THE GOVERNMENT

This section will discuss the costs and risks of warranties as they pertain to the Government. The topics treated include warranty price, warranty price with regard to the reliability improvement warranty, warranty administration, warranty effect on long-term operational costs, costs of warranties for dual sources, reduced self-sufficiency, transit times for failed and repaired components, design costs, and finally the risk of not having a warranty at all.

The first cost to be realized with a warranty is the warranty price itself. When the Government requires that a warranty be provided with a procurement, the warranty costs will be included in the purchase price of the equipment, if the warranty is not paid for explicitly as a separate item. This is especially true in reimbursable cost type contracts since it may be

difficult to break out warranty-related costs from the non-related cost elements [7:29]. The inclusion of a warranty as a term and condition of sale will inherently increase the overall price of the purchased equipment as opposed to the price of the same equipment without warranty inclusion. The contractor simply is not going to provide a warranty free of charge, because a contractor must bear considerable cost and risk to support the long term warranty requirements.

The warranty price represents risk to the Government, especially with a reliability improvement warranty [27:1-4]. If improvement parameters are too loosely defined, then the Government may pay an excessive amount for the warranty and not realize a significant improvement in reliability. Warranty price is determined by, among other factors, the expected cost for the anticipated warranty work. If the covered system has historical reliability data available, a good approximation may be possible.

The next significant cost is the cost of warranty administration. Warranty administration is an absolute necessity since most warranties require that covered items not be tampered with except by fully authorized service personnel, usually contractor representatives. To avoid warranty invalidation, particularly since current emphasis is on increasing the use of warranties, the Government is going to need to develop data base management systems to monitor the location of warranted equipment, track failure rates, failure history, warranty maintenance requirements, warranty time remaining on each covered piece, and other data that may be a precondition of the warranty. The intrinsic costs of legal expenses should not to be ignored. While an adversarial relationship between the Government and the contractor is not sought, legal fees should be anticipated because of the

different interpretation of clauses in the warranty provision and the need to enforce rights and claims. [27:1-4]

A long term effect of warranty usage may be reflected by increased system life and, hence, system operational costs. Hopefully, the application of warranties to weapons system will increase the reliability and longevity of the system, especially if the reliability improvement warranty is the type of warranty in force. The increased reliability and maintainability should extend service life, hence, the requirement to continue funding the operating costs over a longer period of time [7:30]. It should be noted conversely, that as the reliability of the system increases, maintenance costs should decrease, although, not necessarily in proportion to operating costs. Some form of continual maintenance will always be required, so even though there may be a decrease in maintenance requirements overall, it may not be sufficient to displace total operating expenses over the full system life.

The Competition Advocate of the United States Navy, Rear Admiral Platt, is strongly in favor of developing dual sources for weapon system acquisitions [28]. Development of dual sources may provoke increased costs in warranty application. Where there are dual sources, the primary contractor may be able to accomplish modifications with little or no cost impact since, the primary source was most likely involved with product development. The second source supplier may not have the same data availability or operating efficiency and therefore, may require greater remuneration to implement the same changes for the same warranty coverage. [7:30]

Warranty usage can reduce self-sufficiency which represents another form of risk to the Government. Since most contract warranties require "hands off" treatment of the covered components, the Government becomes

reliant on the contractor for maintenance and parts support. Due to the nature of military duty, unexpected deployments, emergency actions and other unknown short notice requirements, dependence upon a contractor for warranty support may be a significant risk to the Government. Additionally, unlike the private sector, the military is not plagued with labor disputes. Consequently, military operations tend to continue even when the contractor's labor force may be on strike. This raises the issue of how to maintain contractor support and parts flow while not invalidating an effective warranty if such a preeminent circumstance should arise. [27:1-4]

Pipeline transit times for parts or repaired components represent a risk that should be a concern to the Government. This is particularly the case in the reliability improvement warranty and the mean time between failure warranty. If a very high readiness factor is required, the warranty should include a clause defining reasonable turnaround time for the repair of defective components. Good business sense would dictate that too short of a time puts an undue hardship on the contractor, which in turn, will either raise the price of the warranty or encourage the contractor not to perform. Should the turnaround time requirement be such that it mandates quick response, then the Government should consider the number of required operational units, the number of replacement spares, and their availability during the contract development stage. If however, the total liability of providing spares coverage is the responsibility of the contractor as a provision of the warranty, the cost shifts completely to the contractor but the risk to the Government may remain notably high. [7:29]

Design costs represent a risk to the Government. In the reliability improvement warranty for example, when a piece of equipment fails, the

responsibility to redesign falls on the contractor. The contractor's profit can be enhanced when redesign improves equipment reliability and reduces repair costs. Should the redesign prove too expensive; that is, cost more than the repair effort, the contractor will then use the minimal design modification that is most conducive to the warranty and not necessarily suited to the best military function. [27:1-4]

With respect to design costs, warranty and equipment age can play significant roles in where the contractor will devote the most attention. If modifications to design are required early in the warranty life, the contractor is more apt to make the modifications since there is greater likelihood to recover the costs. In contrast, as the warranty and equipment age, the contractor is inclined to make smaller scale improvements or perform interim fixes in lieu of major modification because cost recovery is unlikely; therefore, Government risk increases with warranty age. [7:30]

Training expenses should not be ignored. There will be a requirement to train personnel to administer the warranty as mentioned before, but just as importantly, technical training will be required so that the system can be maintained and repaired when the warranty ceases.

Finally, as a matter of note, the absolute highest risk the Government can assume is the risk associated with not having a warranty at all. Without any warranty coverage whatsoever, the Government assumes 100 percent risk and responsibility for equipment performance and operation. Once the system is delivered and accepted, the contractor is totally released from any culpability with regard to reliability or performance and, there is no incentive to pursue performance statistics or make design improvements except for the hope of a follow-on contract at some future time.

D. COSTS AND RISKS TO THE CONTRACTOR

The costs and risks that the contractor must face are examined in this section. The subjects investigated are, warranty price considerations for the contractor, subcontractor risk, effect of mean time between failure threshold, cost of testing, Government paperwork delays, misuse or abuse of equipment, engineering design risk, specialized production expense, ripple effect, quality control, warranty administration, and latent defects.

The contractor faces a similar risk to the Government with respect to warranty price. While the Government is concerned whether too much was paid for the warranty, the contractor is concerned whether enough was charged to recover costs plus some profit. Again, if a new technology is involved, contractor risk will be significant due merely to the inability to predict with sufficient accuracy the frequency of failure or the cost to repair. [27:1-6]

The contractor may experience considerable risk when forced to procure system parts from subcontractors. The subcontractors may not warranty their parts for the duration agreed upon by the primary contractor which forces the primary contractor to assume the risk and responsibility to effect repairs regardless of who manufactured the part. Contractor risk can be reduced through active negotiation with subcontractors to develop parity of warranty coverage.

In the mean time between failure warranty, the contractor is exposed to considerable risk. If the negotiated mean time between failure threshold is established at a level significantly higher than the actual equipment performance, then the contractor must (1) make corrections or redesign at his own expense and, (2) can be penalized for failing to achieve a satisfactory

reliability level. Significant misjudgement here can have a notable effect on contractor profit or loss.

Since most warranties specify that the buyer will not attempt to repair or troubleshoot covered components, the contractor is exposed to the expense of testing and returning non-failed items. Costs can be significant in this category, especially with today's "black box" technologies. Also, mishandling or tampering with equipment by untrained or uncaring military maintenance personnel can cause premature failures, increasing contractor risk. [27:1-6]

Government delays in the processing of paperwork, like engineering change proposals, present some degree of risk to the contractor. In the scheme of the reliability improvement warranty, a contractor is supposed to submit engineering change proposals for approval whenever design changes are necessary on covered systems. When the engineering change proposals are approved, the contractor installs the change, reducing warranty maintenance costs, thereby increasing contractor profit. When the Government delays action on the engineering change proposal, the contractor is forced to suffer the loss of potential profit and at the same time, the Government is foregoing or delaying the added benefit of improved system reliability. [27:2-5]

Besides the innate risks associated with engineering change proposal processing delays, the contractor is imperiled by other forms of Government inattention. The contractor is reliant on failure data and other related information to develop appropriate warranty design modifications or repairs. If the Government fails to provide timely, complete, and accurate data, the

contractor is placed at risk because of improper warranty management and the inability to control Government actions. [27:2-5]

The next risk the contractor faces is the misuse or abuse of equipment by the buyer. Once equipment is delivered to the Government, the contractor generally has very little direct control on how the system is used and by who. Consequently, abused or misused equipment that fails is usually returned to the manufacturer for repair under the warranty. Unless there is significant physical evidence to support proof that the equipment was abused (and this is not always easy to prove) then the contractor bears the cost of the repair.

Engineering design represents a form of risk for the contractor, particularly, if the contractor did not participate in the system design. Quite often in the past, the military provided a design to the contractor to manufacture the system according to the specifications. Since the contractor was usually eager to have the business, the system was constructed as directed, with only minor additional attention being paid to actual form, fit, and function. Ultimately when the new system was introduced into service, there was no guarantee that the system would actually perform, and if it did, for how long. If the contractor is required to warranty the system, the risk level is significant in that the Government is requiring the contractor to cover a design that is not directly under the contractor's cognizance or responsibility.

Aircraft design uniqueness is a form of risk to the contractor. The military infrequently buys a standard commercial aircraft. Aircraft of completely different designs place additional procurement and inventory problems on the contractor. Due to the inability in most applications to

have interchangeable parts, the contractor must either establish a new manufacturing capability to meet the requirement or must develop new outside manufacturing sources, if none presently exists. Nonstandard aircraft, especially where state of the art technologies are involved, represent additional risk to the contractor. Allowing that there may be insufficient historical data by which the contractor can establish failure rates, early warranty support becomes a delicate balance of too much or too little inventory. In the case of the mean time between failure warranty, the contractor is required to provide replacement spares to the buyer if threshold reliability is not maintained. If too little inventory is available, the contractor can be assessed damages. If too much inventory is available and not required, the contractor wastes valuable resources which again decreases profits. [7:36]

The antithesis is also a form of contractor risk. Should aircraft reliability levels greatly exceed the predicted failure rate, then the contractor will be maximizing the profit incentive of the contract. It may therefore, appear to the Government that initial reliability levels were established at too low a level and the contractor may be considered to be making excess profit. [27:2-5]

Another form of risk that should be mentioned is represented by the requirement of the contractor to keep production lines either operational or near operational for multiyear procurements. When compared to standard commercial operations, i.e. manufacturing aircraft like the MD-80 or the 747, typically the military buys smaller quantities over a period of several years. As a result, the contractor must keep a specialized production capability available which may not necessarily share a commonality with the

commercial production process. The contractor is consequently forced to bear additional cost of maintaining expanded capability and at least a nucleus engineering and support staff above and beyond normal business scope to provide long-run warranty support for unique military aircraft.

The contractor is at considerable risk and potential dollar expense when component failure causes a ripple effect. Ripple effect is defined as the resultant failure of one or more additional parts due to breakdown of an initial related part. In this circumstance, the contractor may have been responsible for warranty repair on the original failed component, but it is unclear whether the responsibility for repairs to the other component failures caused by ripple effect, extend to the other effected components, particularly when the parts were manufactured by another company. Precedent seems to indicate that the prime contractor or warranty agency is liable for all related repairs.

There is an associated risk issue revolving around quality control. The prime contractor has direct control over the quality effort that will be directed toward the end product. Because of this direct control, the contractor should be able to minimize risk with regard to long-term warranty coverage due to the ability to make the decision on the level of effort and material quality choice. When the prime contractor uses components or parts manufactured by other companies, the degree of quality control may be inferior to that applied to in-house manufactured products. Because the prime contractor provides the warranty coverage, use of parts manufactured by other companies represents some degree of controllable risk. Should the prime contractor opt to increase the quality specifications on outside suppliers, added cost must be anticipated.

Like the Government, the contractor will bear its costs of warranty administration. To support the long-run warranty effort, the contractor will need a trained staff to deal with numerous facets of warranty claims. Additionally, the warranty administrators will require specialized knowledge and training to handle the procurements and warranties under a Government contract. Because the Government is a public sector entity, it must operate under additional rules and regulations that are not applicable to the standard commercial market. This supplementary training adds to contractor cost considerations.

The Government's use of the latent defects clause appears to be a risk issue of major proportion to the contractor. The clause as presently written places no time limitation or dollar expenditure ceiling on latent defects. The contractor perceives this lack of any limitation as an "open door" policy which provides the Government with unlimited ability to charge against the warranty. Examine the following situation. The Lockheed Corporation has been building and delivering the P-3 Orion aircraft to the Navy for over 20 years. Assume a latent defect is discovered, such as, a structural crack that is caused by harmonic vibration. Under the latent defects clause, Lockheed Corporation would be required to render a fix to every aircraft in fleet service regardless of how old the aircraft is or how much cost was accrued by the contractor. This may be an extreme case, but it is not beyond the realm of possibility. Latent defects probably represent the single most significant cost/risk that the contractor must face since there is no means to determine the upper bound on costs that could be charged back to the manufacturer. Additionally, budgeting and accounting for an unknown such as this is very difficult. How can a contractor budget for a contingency cost

such as a latent defect? A latent defect may never be discovered, but if one is, it may have such a drastic ramifications that a reasonable profit could be reduced to a substantial loss.

E. SUMMARY

The use of warranties is not a cost or risk free environment for either the Government or the contractor. As the use of warranties increases, better understanding of true cost versus risk should also increase. Both the contractor and the Government need to cooperate with each other so that each party can derive the maximum benefit from the use of the warranty.

The Government needs to devote special attention to defining realistic reliability requirements. Consideration should include resolution of desired versus required reliability levels. Placing undue or unrealistic requirements on the contractor not only creates an adversarial relationship, but also defeats the intent of the warranty. The Government needs to recognize that the warranty negotiation process is a give and take situation. An unworkable warranty is no warranty at all.

The contractor needs to recognize that the costs and risks associated with warranty usage are not undivided. A realistic, reasonable profit should be expected, but defining absurdly low initial reliability goals to demonstrate a "marked improvement" is not only misleading, but dishonest. As trustees of public revenues, the Government must pursue the best business deal possible. Contractors should not expect the Government to bear the cost of everyday business risk, but the contractor should be paid a fair fee for risk assumed above routine operations that are directly attributable to the unique requirements of military contracts.

V. WARRANTY PRICING MODELS

A. INTRODUCTION

Warranty pricing is a very inexact and difficult process. Both the contractor and the Government must, through some form of analysis, attempt to determine what is a fair and reasonable price for a warranty. Understanding that there are some similarities of cost for both the Government and the contractor should not cloud the fact that cost and risk are not necessarily a 50/50 tradeoff. Valid warranty pricing dictates careful analysis of the specific equipment being purchased and the type of warranty coverage required. The Government and the contractor need to be thoroughly knowledgeable of their own costs and risks and those existing for the other party.

This chapter will focus on several algorithmic pricing models to illustrate possible avenues of approach to the warranty pricing problem. The reader should fully understand that these models are neither a panacea nor do they represent the entire spectrum of possible evaluation models. There are simply too many conceivable variables that are impossible to accurately quantify, making the straight algorithmic approach beneficial only for relatively certain parameters. Finally, a nonanalytical overview of warranty pricing will be presented to further enhance awareness that the analytical models do not cover all aspects of warranty price consideration.

B. WARRANTY MODELS

This section will present models which discuss the free-replacement warranty and the pro-rata warranty. These particular models are examined

to determine warranty cost as measured in terms of indifference price with or without a warranty. Other models discuss warranty planning and evaluation through the analysis of several warranty rebate models. Also included in this section is a discussion of how warranty support can be predicted through the use of learning curves.

1. Blischke and Scheuer

The material in this section comes from Wallace R. Blischke and Earnest M. Scheuer [29]. The researcher has taken free licence with paraphrasing and word changes, but fully acknowledges the concepts and equations as those of Blischke and Scheuer. Subjects covered include a brief analysis of warranty policy, analysis of the free-replacement warranty, and the pro-rata warranty form both the buyer's and seller's view point.

a. Warranty Policy

There are two types of warranty policies to be analyzed, the free-replacement warranty and the pro-rata warranty. As will be seen, the latter incorporates a feature of the former but is a distinct type.

In the free-replacement warranty, the supplier, for a one-time cost of C_1 , will furnish the customer with as many items as necessary to yield service for the warrantied service duration W_1 .

In the pro-rata warranty with warranty period W_2 and free replacement period A , any item failing before time A is replaced at no cost to the customer; if any item fails after service time W_2 the customer must pay the full price of C_2 for a replacement; between time A and W_2 the customer incurs a pro-rata cost. Specifically, the buyer's replacement cost for an item which has served life X is:

$$\begin{cases} 0, & X \leq A \\ \frac{X}{W_2} C_2, & A < X \leq W_2 \\ C_2, & X > W_2 \end{cases}$$

(2.1)

The replacement item has the warranty of a new item.

The viewpoint of the customer will be considered first. The viewpoint of the supplier will be considered separately. The following notation will be used:

X = lifetime of the item (a non-negative random variable);

L = life cycle of the item (anticipated operational life);

$F(\cdot)$ = cumulative distribution function of the item;

$F(t) = 1 - F(t)$

X_1, X_2, \dots = lifetimes of successive items (independently and identically distributed as F);

$$S_k = \sum_{i=1}^k X_i; \quad S_0 \equiv 0;$$

$N(t)$ = number of replacements of the item made in the time interval $(0, t)$;
 $= \max(k: S_k \leq t);$

$M(t) = E[N(t)]$ (the "renewal function");

$\mu = E(x)$; $\sigma^2 = \text{Var}(x)$, (Note: let $\sigma = \text{sigma}$)

$$\mu_W = \int_0^W x \, dF(x) = \text{the "partial expectation" of } X \text{ until time } W;$$

$\tau(t)$ = remaining lifetime of the item in operation at time t (the "excess life")

$$= S_{N(t)+1} - t;$$

and

$F^{(n)}(\cdot)$ = n-fold convolution of $F(\cdot)$ with itself. From renewal theory it can be shown that

$$P[N(t) = n] = F^{(n)}(t) - F^{(n+1)}(t), \quad n=0, 1, 2, \dots$$

where

$$f^{(0)}(t) = \begin{cases} 1, & T \geq 0 \\ 0, & T < 0 \end{cases};$$

and

$$M(t) = \sum_{k=1}^{\infty} F^{(k)}(t)$$

b. The Free-Replacement Warranty--The Customer Point of View

It is important to note that with a free-replacement warranty, the customer does not immediately incur the replacement cost C_1 at the end of the warranty period, W_1 . That cost is not incurred until the failure of the item then in service at the time $Y > W_1$, where $Y = W_1 + \partial(W_1)$. It is easy to prove that

$$E(Y) = \mu[1 + M(W_1)], \quad (2.2)$$

so that over the life cycle the average number of times payment must be made under the free-replacement warranty is for large L , $1 + L/E(Y) = 1 + L/[\mu(1 + M(W_1))]$. Thus the average total life cycle cost of the item with a free-replacement warranty is

$$C_1(1 + L/[\mu(1 + M(W_1))]) \quad (2.3)$$

If no warranty were in force, a replacement cost of K would be incurred, on the average, $1 + M(L)$ times, so that over the life cycle the

average total cost would be $K[1+M(L)]$. Equating this to (2.3), the cost C_1^* , is found for a free-replacement warranty at which the customer would be indifferent between buying the item with or without warranty. The ratio of indifference price with free-replacement warranty to price without warranty is

$$\frac{C_1^*}{K} = \frac{\mu[1+M(L)][1+M(W_1)]}{\mu[1+M(W_1)]+L} \quad (2.4)$$

If the length of the item's life cycle is sufficiently long, it may be worthwhile to include, in the preceding analysis, discounting of future payments at rate ζ back to time zero. With the free-replacement warranty, payments of C_1 are made, on the average, at time intervals of length $E(Y)$. Thus the average present value of all payments into the indefinite future is

$$\begin{aligned} C_1 \sum_{j=0}^{\infty} \exp[-j\zeta E(Y)] &= C_1 \{1 - \exp[-\zeta E(Y)]\}^{-1} \\ &= C_1 \{1 - \exp[-\zeta \mu [1+M(W_1)]]\}^{-1} \end{aligned} \quad (2.5)$$

Similarly, if one discounts the payments of K made, on the average, at intervals of duration μ when no warranty is in effect, the average present value of all these payments into the indefinite future is

$$K \sum_{j=0}^{\infty} \exp(-j\zeta \mu) = K[1 - \exp(-\zeta \mu)]^{-1} \quad (2.6)$$

Equating (2.5) and (2.6) yields

$$\frac{C_1^{**}}{K} = \frac{\{1 - \exp(-\zeta \mu [1+M(W_1)])\}}{1 - \exp(-\zeta \mu)} \quad (2.7)$$

as the ratio of indifference price under free-replacement warranty to unwarranted price when present value of future payments is considered.

c. The Pro-Rata Warranty--The Customer Point of View

Expected cost is needed, R , of any replacement item. This is given by

$$\begin{aligned} R &\equiv \frac{C_2}{W_2} \left[\int_A^{W_2} x dF(x) + \int_{W_2}^{\infty} W_2 dF(x) \right] \\ &= \frac{C_2}{W_2} [\mu_{W_2} - \mu_A + W_2 \bar{F}(W_2)]. \end{aligned} \quad (2.8)$$

Conditional upon there being exactly n replacements over the item's life cycle (i.e., upon $N(L) = n$), the expected cost over the life cycle under pro-rata warranty is

$$C_2 + nR = C_2(1 + n/W_2[\mu_{W_2} - \mu_A + W_2\bar{F}(W_2)]).$$

Unconditioning on $N(L)$, we obtain for the expected cost over the life cycle under pro-rata warranty

$$C_2 \left\{ 1 + \frac{M(L)}{W_2} [\mu_{W_2} - \mu_A + W_2 \bar{F}(W_2)] \right\} \quad (2.9)$$

Without warranty, the expected cost over the life cycle is $K[1+M(L)]$. Equate this to (2.9) to get

$$\frac{C_2^*}{K} = \frac{W_2[1 + M(L)]}{W_2 + M(L)[\mu_{W_2} - \mu_A + W_2 \bar{F}(W_2)]} \quad (2.10)$$

as the ratio of indifference price under pro-rata warranty to price without warranty.

If present value of future costs into the indefinite future with and without pro-rata warranty are equated, the result

$$\frac{C_2^{**}}{K} = \frac{W_2}{\mu_{W_2} - \mu_A + W_2 \bar{F}(W_2)} \quad (2.11)$$

is the ratio of indifference price under pro-rata warranty to price without warranty when present value is taken into account. Note that the discount rate is not involved in (2.11). This comes about because payments would be made at the same times with or without pro-rata warranty. Equation (2.11) can also be obtained directly by equating K with R.

d. The Free-Replacement Warranty--The Seller's Point of View

The focus now turns to the seller's interests. These are understood to be the determination of selling prices under the two warranties that would yield the same long-run expected profits for him if he offered no warranty. Profit is simply the difference between his revenue (the cost to the customer) and his costs. In the free-replacement warranty the seller's revenue per warranty period is fixed (at C_1), while his costs are a random variable, since the number of free-replacements he must make is random. It is necessary to obtain the expected value of these costs.

In the free-replacement warranty, the expected number of units supplied per warranty cycle (i.e., the time between payments) at no (additional) charge is $M(W_1)$. If each unit costs the seller an amount g , the

Consider a fairly general sampling situation in which there is so-called incomplete data, i.e. the time-to-failure for some items, and periods of observation on other items which may or may not begin at the inception of use of the item and may or may not end with the failure of the item. A nonparametric estimate $\hat{F}(\cdot)$ of $F(\cdot)$ has been provided by Kaplan and Meier [30] for this circumstance. Their estimator is a step function which reduces to the empirical cumulative distribution function in the case of complete samples. With this estimate of $F(\cdot)$ one can in turn estimate $\mu = E(X)$, $\sigma^2 = \text{Var}(X)$ (if needed), μ_B , $F^{(k)}(\cdot)$, $P[N(t) = k]$, $M(t)$, etc., from the following formulas, valid for non-negative random variables:

$$\mu = \int_0^{\infty} [1-F(t)] dt,$$

$$\sigma^2 = 2 \int_0^{\infty} t[1-F(t)] dt - \mu^2,$$

$$\mu_B = \int_0^B [1-F(t)] dt,$$

$$F^{(k)}(t) = \int_0^t F^{(k-1)}(t-x) dF(x),$$

$$P[N(t) = k] = F^{(k)}(t) - F^{(k+1)}(t), \quad k = 0, 1, 2, \dots$$

$$\begin{aligned}
 M(t) = E[N(t)] &= \sum_{k=0}^{\infty} k \cdot P[N(t) = k] \\
 &= \sum_{k=1}^{\infty} F^{(k)}(t) .
 \end{aligned}$$

Substituting the step function $\hat{F}(\cdot)$ into the preceding formulas yields sums in place of integrals in the equations which will then yield estimates

$$\hat{\mu}, \hat{\sigma}^2, \hat{\mu}_B, \hat{F}^{(k)}(t), \hat{P}[N(t) = k], \text{ and } \hat{M}(t).$$

The Kaplan-Meier procedure yields $\hat{F}(\cdot)$ and successive convolutions are obtained in straightforward fashion. There need be some concern, however, about core storage and time limitations in the computer determination of $\hat{F}(\cdot)$ and the convolutions $\hat{F}^{(k)}(\cdot)$, particularly if the sample contains a large number of failure times and if more than just a very few convolutions are needed.

The Kaplan-Meier estimator $\hat{F}(\cdot)$ is of the form

$$\hat{F}(t) = \begin{cases} 0, & t < a_1 \\ h_1, & a_1 \leq t < a_2 \\ \vdots & \\ h_m, & a_m \leq t < a_{m+1} \\ 1, & t \geq a_{m+1} \end{cases}$$

where $a_1 < a_2 < \dots < a_{m+1}$ are the ordered failure times and $0 < h_1 < h_2 < \dots < h_m < 1$. $\hat{F}^{(2)}(\cdot)$ will similarly be a step function and, unless there is some coalescing, the number of steps will be $(m+2)(m+1)/2$. The number of steps in $\hat{F}^{(3)}(\cdot)$ can be as large as $(m+2)(m+1)^2/2$. Generally, $\hat{F}^{(k)}(\cdot)$ can involve as many as $(m+2)(m+1)^k/2$ steps. This soon imposes excessive demands on storage capacity and on computation time.

Fortunately, it is often not necessary to compute too many convolutions. If one is interested in $P[N(W) = n]$, he must calculate $F^{(n)}(W)$ and $F^{(n+1)}(W)$ and take their difference. It would probably not be desirable for either customer or seller if there were a non-negligible probability of needing quite a few replacements over a warranty period W .

In order to obtain μ one needs to calculate $\hat{F}(t)$ completely, i.e. from $t = 0$ until the smallest t for which $\hat{F}(t) = 1$. If computer core space is at a premium, one needs only to calculate the successive convolutions $\hat{F}^{(k)}(t)$ for t up to the length of the warranty period W . Since the life cycle L is generally very long, one might be able to get away with taking

$$M(L) = \frac{L}{\mu} + \frac{\sigma^2}{2\mu^2} - 1/2$$

To reduce computations and storage requirements, it is convenient to lump steps in the $\hat{F}^{(k)}$ that are within some small distance β of each other. In some computations made, $\beta = 10^{-3}$ was taken.

To illustrate the growth of the number of steps in successive convolutions, the following numbers are cited. In an incomplete sample of lifetimes of an aircraft component, 48 actual failure times were observed. Then $\hat{F}(t)$ has 49 steps, $\hat{F}^{(2)}(t)$ can have as many as 1176 steps, $\hat{F}^{(3)}(t)$ can

have as many as 56,448 steps, and $\hat{F}^{(4)}(t)$ can have as many as 2,709,504 steps.

The following are some calculated values from the data just mentioned for an 8000 hour warranty period:

$$\hat{\mu} = 6069 \quad \hat{F}(8000) = .1564$$

$$\hat{\sigma} = 1914$$

$$\hat{P}[N(8000) = 0] = .1564$$

$$\hat{P}[N(8000) = 1] = .7742$$

$$\hat{P}[N(8000) = 2] = .0686$$

$$\hat{P}[N(8000) = 3] = .0007$$

$$\hat{M}(8000) = .9135$$

$$\hat{\mu}_{8000} = \int_0^{8000} [1 - \hat{F}(t)] dt = 5918.$$

Thus for a free-replacement warranty with warranty period 8000 hours, and life cycle 100,000 hours, the estimate of the ratio of indifference price with warranty to price without warranty from (2.4) is

$$\frac{\hat{C}_1^*}{K} = \frac{6069 [1 + 100,000/6069][1 + .9135]}{6069[1 + .9135] + 100,000} = 1.818.$$

For a pro-rata warranty with warranty period 8000 hours, initial free-replacement period 0, and life cycle 100,000 hours, the estimate of the ratio of indifference price with warranty to price without warranty from (2.10) is

$$\frac{\hat{C}_2^*}{K} = \frac{8000[1 + 100,000/6069]}{8000 + (100,000/6069)[5918 + 8000(.1564)]} = 1.109$$

The above presentations of the Blischke and Scheuer models show that warranties must be evaluated on their own criteria. It is also important to understand that as discussed in Chapter IV, the Blischke and Scheuer models demonstrate that the more warranty coverage required, the more it will cost. Note from above, the 81.8 percent cost for the free-replacement warranty as opposed to the 10.9 percent cost for a pro-rata warranty. Clearly, the Blischke and Scheuer models do not cover all facets of warranty cost and they assume that both the buyer and seller have respective knowledge of product failure rates. This assumption may not be true, especially if a new product is being developed under a reliability improvement warranty.

2. Thomas

The rebate models and examples presented in this section are the work of Marlin U. Thomas [31]. In the interest of brevity, this researcher has omitted portions of Thomas' paper, but the analysis and results have not been altered. Warranty models are presented to examine the cost-benefit tradeoffs where the buyer receives a total rebate for equipment failures. The prorated rebate model and the renewable warranty are also examined.

a. Background

If product quality is high, then the cost of the warranty will be relatively low and whenever a low product line or lot is released the manufacturer will eventually be penalized by increasing warranty expense. If low quality production continues repeatedly over time then the market position of the product becomes threatened. In general, a minimum cost warranty program is a vital element for overall cost control in manufacturing. This requires a sound planning program.

The development of a warranty planning program requires a good knowledge and control of the relationship among quality, reliability, and warranty cost. The models presented examine these relationships. The first model is the policy of total rebate for any failure occurring during the warranty period. This policy is typically applied for relatively inexpensive production units with moderate to high product reliability. Next, the prorated rebate policy is considered whereby total compensation is rendered for failures that occur before a fixed time. Beyond this time the failures that occur during the remaining warranty period result in prorated compensation to the buyer. This policy is generally applied to moderately expensive items. In the next section, a policy is described where the warranty is renewed if failure occurs within a specified time. Here it is possible for a consumer to have an infinite warranty period for a single purchase. This is the least common policy and is typically granted only for highly reliable inexpensive items.

b. Rebate Models

Consider a manufactured product with failure time T distributed $F(t)$ for which a rebate cost $A(w)$ is incurred for each failure that occurs during a warranty period $(0, w)$. Since the prime motivation for warranties is to penetrate or maintain a market, assume that the expected benefit $B(w)$, $w \geq 0$, is realized through a favorably decreasing market cost. In addition, the routine costs for warranty administration is assumed to be fixed at K_w . The aggregate expected total cost function is

$$C(w) = A(w) + B(w) + K_w, w \geq 0. \quad (1)$$

In order to find the optimum warranty period W^* , the cost components must be quantifiable. It is very difficult in general to specify

$B(w)$ due to the many uncertainties involved. For this discussion, $B(w)$ will be treated as linear and $B(w) = b_0 - b_1 w$, $w \geq 0$. It therefore follows that

$$C(w) = c \int_0^w f(u) du + b_0 - b_1 w, w \geq 0 \quad (2)$$

where c is the unit cost, in dollars, of failures during $(0, w)$. To find an optimum interval length, straightforward differentiation leads to

$$w^* = f^{-1}\left(\frac{b_1}{c}\right) \quad (3)$$

provided $f'(w) > 0$.

(1) Example -1. As an example suppose a manufacturer wants to warranty a product that has an exponential failure time distribution with a mean-time-to-failure of $1/\pi$. Thus in (3)

$$f(t) = \begin{cases} \pi e^{-\pi t}, & t \geq 0 \\ 0, & \text{otherwise} \end{cases}$$

and the optimum warranty interval length is given by

$$w^* = 1/\pi \cdot \ln(c\pi/b_1) \quad (4)$$

Suppose the mean-time to failure is 1.5 years and the failures result in a unit warranty cost of \$200. Further, from a marketing study the impact of warranty on marketing expense is estimated at $A(w) = 200 - 20w$, $0 < w < 10$, dollars per unit. Therefore, $\pi = 2/3$, $c = b_0 = 200$, and $b_1 = 20$ from which it follows from (4) that $w^* = 2.85$ years or approximately 34 months.

c. Prorated Rebate Model

The results of (2) and (3) apply to the case whereby the buyer experiencing a failure during $(0, w)$ receives total compensation. Now consider a more general model for which a manufactured item is warranted such that the buyer is given total rebate if failure occurs during a fixed interval $0 \leq t \leq w_1$ and prorated compensation if failure occurs during $w_1 < t \leq w_2$. The total cost is given by

$$A(w_1, w_2) = c \int_0^{w_1} f(t) dt + c \int_{w_1}^{w_2} \frac{w_2 - t}{w_2 - w_1} f(t) dt \quad (5a)$$

or

$$A(w_1, w_2) = \int_{w_1}^{w_2} \frac{cF(t)}{w_2 - w_1} dt \quad (5b)$$

Policies of this type are applied to moderately valued products that render significant but well defined wear. Note that for the special case of $w_1 = w_2 = w$ in (5a) the result is the same as the total rebate model.

To find an optimum warranty interval $(0 \leq w_1 \leq w_2)$ for this policy one can proceed formally by substituting the rebate cost from (5b) into the expected total cost function of (1). Thus,

$$C(w_1, w_2) = \int_{w_1}^{w_2} \frac{cF(t) dt}{w_2 - w_1} + B(w_1, w_2), \quad (0 \leq w_1 \leq w_2) \quad (6)$$

where $B(w_1, w_2)$ is a function of the prorata interval. To minimize (6) solve the system of equations derived from setting

$$\partial/\partial w_1 C(w_1, w_2) = \partial/\partial w_2 C(w_1, w_2) = 0.$$

Still another approach for finding an optimum policy is to apply the following result.

(1) Proposition 1. For each prorated policy defined over an interval $I_1 = \{t: t \ (0 < w_1 \leq w_2 < \infty)\}$ there is a cost equivalent total rebate policy over $I_0 = \{t: t \ (0 < w < \infty)\}$, where $w_1 \leq w \leq w_2$.

Consider a prorated policy over I_1 . From (5b)

$$A(w_1, w_2) = \int_{w_1}^{w_2} \frac{cF(t)}{w_2 - w_1} dt, \quad t \in I_1$$

Now find a w such that $A(w) = A(w_1, w_2)$. Thus,

$$C \int_0^w f(t) dt = \int_{w_1}^{w_2} \frac{cF(t) dt}{w_2 - w_1}, \quad 0 < w_1 \leq w \leq w_2 \quad (7)$$

Proposition 1 is based on the implicit assumption that the comparable marketing cost function are equal, i.e. $B(w) = B(w_1, w_2)$. Given a rebate policy over I_1 , determination of the interval I_0 by computing a value w' satisfying (7) can be done. Compare this value to the optimum interval length w^* given by (3).

(2) Example - 2. Again, let T be exponentially distributed as in Example 1 with

$$F(t) = \begin{cases} 1 - e^{-\pi t}, & t \geq 0 \\ 0, & \text{otherwise} \end{cases}$$

From (7),

$$F(w) = 1 - \frac{e^{-\pi w_1} - e^{-\pi w_2}}{\pi(w_2 - w_1)}$$

from which it follows that

$$e^{-\pi w} = \frac{e^{-\pi w_1} - e^{-\pi w_2}}{\pi(w_2 - w_1)}$$

and using the second order approximation

$$e^{-\pi w} \approx 1 - \pi w + \frac{(\pi w)^2}{2}$$

find

$$w' = 1/\pi \pm 1/\pi \sqrt{1 - \pi(w_1 + w_2)} \quad (8)$$

where $\pi < (w_1 + w_2)^{-1}$.

Suppose $\pi = 1/15$ failures per month and the policy is to provide full compensation for failures occurring within 6 months and prorated compensation for failures that occur between 6 months and one year (i.e. $w_1 = w_2 = 6$). From (8) obtain $w' = 8.29$ months, and hence the equivalent total rebate policy is to provide full compensation for failures that occur up to that point in time and nothing thereafter.

d. Recurring Warranty Period Model

Thus far cases have been treated where the probability of a particular product having more than one failure in $(0, w)$ is very small. Now consider the warranty policy whereby if a failure occurs during $(0, w)$ then the buyer receives full compensation at a cost to the manufacturer of c dollars per unit and the warranty intervals starts over.

So the number of effective warranty intervals N for a given buyer is distributed geometrically with discrete probability function

$$g(n) = [1 - F(w)][F(w)]^{n-1}, w > 0, n = 1, 2, \dots \quad (9)$$

The particular warranty rebate cost for a particular product is therefore,

$$A(w) = c/1-F(w) \quad (10)$$

It now becomes necessary to consider the warranty lifetime, T , which is the effective warranty duration for a product. This time then extends from purchase until the first failure occurs outside its respective warranty interval. Thus,

$$T = \sum_{i=1}^N T_i$$

where the product failure times $T_i, i=1, 2, \dots$, form a sequence of independent random variables each distributed $F(T), t \geq 0$.

(1) Proposition 2. Letting the probability density function for T_i have Laplace Transform

$$\bar{f}(s) = \int_0^{\infty} e^{-st} f(t) dt, \text{Re}(s) > 0$$

for each $i=1, 2, \dots$, the Laplace Transform of the probability density function for T is given by

$$\bar{h}_T(s) = \frac{[1-F(w)]\bar{f}(s)}{1-\bar{f}(s)F(w)}, w > 0, \text{Re}(s) > 0. \quad (11)$$

Since $T_i, i=1, 2, \dots$ is an independent sequence, the conditional probability density function for T given $N = n$ is the n -fold convolution of $f(t)$ with itself. Therefore, for general $g(n)$,

$$\bar{h}_T(s) = \sum_{n=1}^{\infty} [\bar{f}(s)]^n g(n) = G[\bar{f}(s)] \quad (12)$$

where

$$G(z) = \sum_{n=0}^{\infty} z^n g(n)$$

is the probability generating function for $G(n)$. For N geometric, substituting (9) into (12) gives the results of (11).

Proposition 2 is useful in determining the relationship between the warranty lifetime T and the failure times T_i , $i=1, 2, \dots$. From the moments of $h_t(s)$ for $s \rightarrow 0$ one obtains the warranty lifetime mean and variance relationships

$$E[T] = \frac{E[T_i]}{1 - F(w)} \quad (13a)$$

$$\text{Var}[T] = \frac{\text{Var}[T_i]}{1 - F(w)} + \frac{F(w) E^2[T_i]}{[1 - F(w)]^2} \quad (13b)$$

Now to determine an optimum warranty interval W^* formulate the expected unit warranty cost function of (1) with $A(w)$ given by (10),

$$C(w) = c / 1 - F(w) + b'_0 - b_1 w \quad (14)$$

Assume the marketing cost is a linear function $B(w)$. A value w^* minimizing (14) is not available in closed form, but can be determined or approximated for a particular $F(w)$.

(2) Example - 3. Continuing with the case of exponential failure times with mean $1/\pi$,

$$F(s) = \pi/\pi+s, \text{Re}(s) > 0$$

so

$$F(w) = 1 - e^{-\pi w}, w \geq 0, \text{ and in (11)}$$

$$\bar{h}_T(s) = \frac{\pi \exp[-\pi w]}{\pi \exp[-\pi w] + s}, \text{Re}(s) > 0$$

which is the Laplace Transform for the probability density function

$$h_T(t) = \pi \exp[-\pi w] e^{-\pi \exp[-\pi w] t}, t \geq 0 \quad (15)$$

Thus, for exponentially distributed failure times the warranty lifetime T is also exponentially distributed but with a rate weighted by the probability of a failure occurring outside a warranty interval. The warranty lifetime mean and variance is therefore $e^{\pi w}/\pi$ and $(e^{\pi w}/\pi)^2$, respectively, which also follows from (13a) and (13b).

From (14) the total expected unit warranty cost is

$$C(w) = ce^{\pi w} - b'_w + b'_0 \quad (16)$$

from which it follows that the minimum cost warranty interval is given by

$$w^* = 1/\pi \ln(b_1/c\pi), b_1 > c\pi. \quad (17)$$

Note that this result is the same as that obtained in the simpler one time rebate model of (4), only here the ratio of the slope of the benefit function $B(w)$ to $c\pi$ must be greater than 1.

e. Conclusion

Warranty planning like any other planning function involves goal setting, performance assessment, and action plan development for future products. The models described here are useful in carrying out these activities. These models allow management to examine warranty policies under some relatively broad conditions. Still, there are some limitations and

needs for extension. The general total expected warranty cost function of (1) can take on a variety of forms but the most common function will have convex components $A(w)$ and $B(w)$. Only a slight extension is required in order to accommodate other choices of convex $B(w)$, $w \geq 0$. The benefit of a warranty is indeed the most difficult cost component to assess, but it is necessary in order to examine cost and warranty interval tradeoffs and establish goals.

The results reported here hold for a general failure time distribution $F(t)$, $t \geq 0$. The examples have treated the important special case of exponentially distributed failure times. While this is clearly the simplest case analytically, it is also commonly used in planning studies. Other important failure time distributions to be dealt with are the Weibull and Log-Normal. These require more computations, but conceptually pose no greater difficulties. In addition, these results can be extended to include discounting and inflation considerations by incorporating the appropriate factors in (2) and (14).

3. Barton

In this section Harvey Barton [32] offers an interesting variation on using learning curves to predict warranty support requirements. The work is entirely that of Mr. Barton, but it is included for the reader's consideration and evaluation. As before, the researcher has taken some liberties with wording and has edited the article for brevity.

a. Introduction

The 1984 Defense Appropriations Act requires the Government to obtain warranties for performance as well as freedom from defects. One aspect of performance subject to such warranties is reliability. If the

requirement is demonstrable by test, there seems to be a basis to limit the warranty duration to that of the test. In these early stages of application of the warranty requirements, the required duration is still being explored. Such requirements have included evaluation in field operation of equipment, and for longer periods than normally encountered during implant tests.

The major problem in such evaluations is the lack of maturity of the equipments used as the basis for test. Early failures are likely from defects in parts, defects in assembly workmanship, and correctible design errors. In fact, workmanship errors are likely to predominate. Reliability improvement of the fielded units will be obtained in the normal course of fixing these failures. Some parts defects will be corrected only by substitution of different parts types of vendors. Such corrections confer initial reliability improvements upon future equipment deliveries. Future deliveries are also enhanced by feedback of workmanship problems for corrective action and are affected in the normal course of correction of design defects. The risk inherent in these situations can be reduced with consideration of equipment reliability growth. The objective is to estimate the expected number of failures during a proposed warranty period and the resulting cost to implement the warranty. This has been attempted through the use of learning curves to estimate reliability growth. The application requires establishment of a reliability estimate for a specific equipment age and an expected rate of reliability growth.

b. Learning Curves

Learning curves were first used in the aircraft industry, to forecast the effect of learning on production rate per hour. The analysis of World War II data indicated that production efficiency increased

logarithmically with respect to production quantity. The relationship appeared to conform to the following expression:

$$Y = Ax^{-b} \quad (1)$$

where

Y = average cost per unit

A = cost of the first unit

x = number of units produced

b = the "slope" parameter

Since the original applications to forecast labor costs for aircraft assembly, the learning curve has been found to fit a wide variety of operations.

Because of the characteristics of equation (1), a meaningful method was found to represent the rate of improvement, or slope, of the learning curve. This measure relates the percentage of improvement for each doubling of production quantity, and is a constant. In an 80 percent learning curve, for instance, each doubling of production quantity reduces average unit labor to 80 percent of the previous level. If the average cost for 100 units is \$10; the average cost for 200 units will be \$8, and the average cost for 400 units will be $(0.8 \times \$8. =) \6.40 . Different kinds of operations appear to tend toward different slope values, and analysts have found it convenient to estimate "learning factors" from the content of an operation. The following table lists a few learning factors and corresponding slope parameters.

<u>Learning Factor</u>	<u>Slope Parameter (b)</u>
95%	0.074
90%	0.152
85%	0.234
80%	0.322
75%	0.415
70%	0.515

The relationship of the learning curve is useful for many functions showing exponential decay. The reliability growth model used by Duane [33] and others is identical to the learning curve relationship. A better understanding of the identity may be had from a comparison of parameter definitions. The following repetition of equation (1) is accompanied by parameter definitions used for manufacturing cost projection, and corresponding definitions for reliability growth.

$$Y = Ax^{-b}$$

<u>Parameter</u>	<u>Manufacturing</u>	<u>Reliability</u>
Y	= Average cost per unit	= Cumulative failure rate
A	= First unit cost	= Initial failure rate
x	= Number of units produced	= Cumulative operating hours
b	= "slope" parameter	= "slope" parameter

The similarity of definitions is interesting. It should be noted that the value of "A" is not measured directly in either application. In estimation of manufacturing cost, the "first unit cost" is determined from the other parameters, and used for extension to different production quantities. By the same token, "initial failure rate" is not measurable directly, and is referred to as "constant". It may be useful to recognize it as the initial failure rate, for the same purpose as used for "first unit cost". The fact that the "reliability growth curve" is a learning curve seems to provide a basis for using the learning factor as a measure of slope. Such a relationship was being used for reliability growth by the mid 1950's. Fielded electronic equipment was shown to improve in reliability logarithmically with

respect to equipment age. The rate of reliability improvement varied depending upon how well faults were removed from equipment before delivery and the nature of corrective action after delivery.

In recent applications to reliability growth, the learning curves have lost their identity, being called "Reliability Improvement Curves" or "Reliability Growth Curves". The trends and mathematical relationships are the same as they were in Duane's analyses, which recognized the concept of the "Learning Curve". Recognition of the commonality of reliability growth and learning relationships seems very useful to visualizing the reliability growth phenomenon. The Program Manager will find it easier to evaluate a 70 percent learning curve than a reliability improvement slope of 0.515. Therefore, the commonality of relationships is discussed here.

MIL-STD-1635 and MIL-STD-189 treat the concept of reliability growth. MIL-STD-1635 describes requirements for Reliability Growth Testing. It is useful in estimating the cost of a reliability warranty, based upon application of learning curves.

c. Application of Learning Curves

Two parameters are necessary to apply the learning curve to the prediction of warranty support requirements. The slope and intercept of the expected reliability growth curve will define its position and the expected number of failures. In addition to definition of the expected reliability during the warranty evaluation period, an estimate must be made of the cost consequences of a failure. The cost aspect of the problem will not be treated in detail here. The cost consequences of failure may include feedback of corrective action to changes in design and manufacturing processes, or may be limited to the repair actions at failure. Costs are estimated to fulfill

contract requirements, and may be subject to negotiation of warranty terms.

d. Learning Curve Slope

The slope of a learning curve can be expressed as the slope of the straight-line representation on log-log paper, or as the relationship of reliability levels at two points in time with a 2:1 ratio of operating hours. An 80 percent learning curve would represent a rate of improvement such that the failure rate at 2000 hours would be 80 percent of the failure rate at 1000 hours. The slope of such a curve on log-log paper would be 0.322.

MIL-STD-1635 describes the probable range of slopes to be between 0.3 and 0.6, depending upon the corrective action program invoked. Other references report slopes as small as 0.2, for equipment having failures screened out before official reliability testing. It seems obvious that removing the most likely failures before test will reduce the potential for early failure during test, and therefore reduce the rate of improvement from that point. If all defective parts, design errors, and workmanship errors could be eliminated by pre-screening, reliability growth would be nil.

The most reasonable estimates of slope appear to be in the range of 0.3 to 0.5, corresponding to learning factors of about 70 percent to 80 percent.

The expected value of slope is somewhat controllable by the amount of screening used to eliminate potential failures. The desirability of such screening varies, depending upon contract type and criteria of acceptable performance.

If the acceptance criterion comprises the demonstration of an acceptable trend, then pre-screening may make it much more difficult to

demonstrate the trend by eliminating failures which would provide an anchor for the origin of the MTBF trend. This is illustrated in Figure 1.

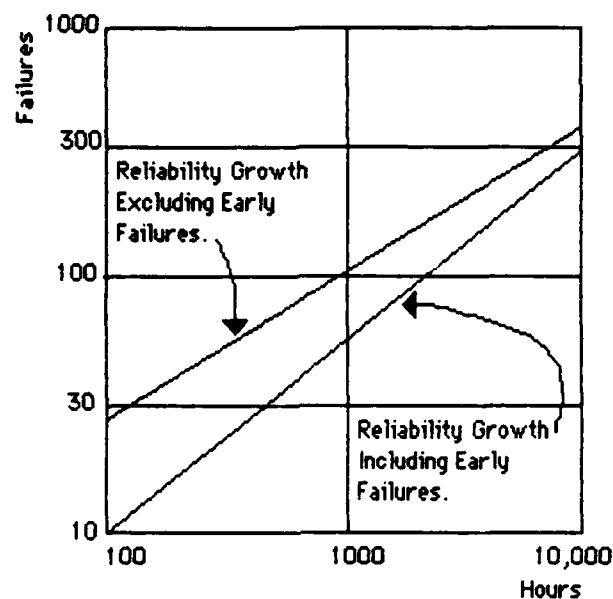


Figure 1. Reliability Improvement Affected by Censoring Early Data

The upper line shows a reliability growth curve constructed from hypothetical test data from MIL-STD-1635. The lower line shows the result of censoring out the first hundred hours of operation and failures. Obviously, the apparent rate of improvement has been reduced. Although this illustration uses well-behaved hypothetical data, the effect is likely to be more emphatic in a real-life program, where a rash of early failures may occur at turn-on. In a fixed-price contract, some screening may be desirable to limit the field support costs of the warranty, especially if the warranty requires achieving some level of reliability during warranty period. A cost reimbursable contract gives no incentive to screen. In such a case, the negotiated length and acceptance basis for the warranty period should determine the desirability of screening. Short warranty periods need all the data they

can get to show a trend, if reliability growth is an acceptable criterion, so screening is undesirable. If average field performance during the warranty period is the criterion, all possible potential faults should be eliminated by screening.

e. Baseline MTBF

MIL-STD-1635 establishes an intercept at 100 hours of test time or one-half the predicted MTBF, whichever is greater. At this intercept the cumulative MTBF is postulated to be ten percent of the predicted MTBF. This appears to be a conservative estimate for our purposes. The value of this intercept appears to depend upon the effectiveness of prior screening tests. Screening appears to have its greatest effect early in an equipment's life. From the reviewed reference data, the cumulative MTBF at such a test time can be as high as twenty-five percent of predicted MTBF. This range can be part of the basis for competitive risk analysis and negotiation.

(1) Defining Warranty Criteria. The considerations of reliability growth can be used to influence warranty measures as well as estimating warranty cost. Early test data could be used to show a trend toward the reliability goal before the goal is reached.

Duration of a warranty period for reliability could be limited to the requirement to show a learning trend toward the MTBF goal. The cost of supporting the warranty period can be predicted with consideration of the expected reliability trend for the duration of the warranty period. A historical basis exists for prediction of reliability improvement throughout any conceivable warranty period. Therefore, the rate of improvement becomes a more valid measure of equipment reliability than average performance during the warranty period.

Development of a competitive warranty program can benefit from certain cost tradeoffs. The cost of a screening program may be effective in either of two ways. If the screening data are used to measure reliability growth, they add data points and enhance the improvement rate. If screening data are excluded from warranty evaluation, a higher average reliability may be shown for the warranty period, with fewer field failures to be supported.

The feedback effect of corrective action to design and manufacturing processes depends upon the warranty population delivery rate. If the corrective actions can be incorporated for a significant portion of the warranty, they can enhance measured reliability growth. On the other hand, if the warranty period is short, and/or covers only an initially-delivered number of equipments, such corrective actions may not affect the measured equipment nor help warranty evaluation. In such a case, reliability improvement will result from removal of defective parts, repair of solder joints, etc. This means of reliability improvement exists because of the variability of electronic parts and the presence of some marginally defective parts in any population. Removal of these parts when they fail improves the average reliability of the remaining population. This occurs because the replacement parts have smaller defect rates than those being replaced, assuming that the replaced parts are mostly defective. Additional sources of reliability improvement include repairable parts and processes, such as solder joints. If a marginal solder joint is repaired, its probability of later failure is reduced. These methods have been proven effective, with equipment reliability improvement throughout measured life.

f. Conclusions

Learning curves can be used in prediction of warranty support requirements. The learning curve improvement percentage factor is a useful measure of the rate of reliability improvement. It offers a tangible measure of improvement rate which the Program Manager can relate to other applications of the learning curve, as for manufacturing costs.

Prediction of reliability improvement requires estimation of the learning rate and a point estimate of reliability. The expected range of learning rates is from 70 percent to 80 percent, corresponding to exponential slopes of about 0.3 to 0.5. Reliability screening tests may be expected to reduce the subsequent learning rate by elimination some of the early failures. The learning rate could be estimated at 70 percent (or 0.5 slope) if all data are used, or about 80 percent (0.3 slope) if prescreened data are censored from consideration.

The initial value of reliability may be estimated as the cumulative MTBF when test time equals one-half the MTBF. The reliability may be estimated at ten percent of the predicted MTBF if all data are included, or as much as 25 percent of predicted MTBF with exclusion of the results of a strong screening program.

Evaluation of support requirements by these methods can be a valuable tool in equipment design tradeoff. Support cost drivers can be isolated and subjected to reliability or maintainability improvement.

C. A SIMPLE NONANALYTIC MODEL

The following model is presented to add insight to the difficult task of warranty pricing. It highlights many of the questions and points of interest that must be examined when developing the warranty price. The model was

developed by Dr. Harold Gault, Director of Estimating, for General Dynamics Pomona Division [34]. The model is generated using an eight step process.

1. Step One--Product Warranty Scenario

The first key issue that needs to be understood is, what triggers cost incidence under a warranty.

- * What hardware is covered?
--line items, part numbers, components, subcomponents.
- * When and where does coverage commence?
- * How is a failure ascertained?
--test procedures, inspection methodology.
- * How is a failure verified?
- * How are repairs and corrective actions sold?
- * How and when is the warranty obligation fulfilled?

2. Step Two--Product Warranty Task Statement

Each item must be customized or tailored for the specific product. The warranty task statement must specify which party is responsible for what task. The following tasks should be defined in the warranty.

- * Transport of failed hardware
- * Test hardware required to verify failure
- * Determination of corrective action
- * Repair of hardware and correct documentation
- * Sell-off the repair/correction
- * Transport repaired hardware

- * Maintain configuration accountability and marking
- * Calibrate and maintain support equipment during warranty period
- * Provide warranty administration
 - logistics
 - program management
 - budgets and cost analysis

3. Step Three--Hardware Failure Rate/Documentation Deficiency

Experience reduces conjecture which makes pricing simpler. Ask for advice from the customer; he may have better data.

- * Develop historical average hardware failure rate
- * Develop historical average documentation deficiency rate

Adjust for

- * Reliability growth trends
- * Current commitment parameters
- * Confidence level

4. Step Four--Hardware and Documentation Cost/Correction

- * Historical average cost per hardware repair
- * Historical average cost per documentation correction

Adjust for

- * Learning curve
- * Current commitment parameters
- * Economics

5. Step Five--Summarize Quantity-Based vs. Time-Based Costs

- * Quantity-based
 - Hardware fixes x cost per fix
 - Documentation corrections x cost per correction
 - Items transported x cost per trip
- * Time-based
 - Configuration management
 - Equipment calibration and maintenance
 - Warranty administration

6. Step Six--Itemize Assumptions and Exclusions

- * Assumptions (examples):
 - Follow-on procurements
 - Continued availability of tooling and test equipment
 - Customer test program

Warranty price may be equitably adjusted if assumptions do not hold.

- * Exclusions (examples):
 - Inventory screening
 - Flight failure investigation
 - Contractor costs for processing non-defects

Exclusions may be subject to negotiation or equitable adjustment.

7. Step Seven--Determine Proposed Earnings

Risk is not the same for the basic production task as for the warranty. There are two profit elements to evaluate, compensation for additional production tasks and reward for bearing additional risk.

- * Proposed production contract earnings are a baseline but are not determinative
- * Examine warranty task cost breakdown and variability
- * Consider limitation of financial liability approach

8. Step Eight--Develop a Historical Data Base

Warranty administration is a major issue. Projectable cost experience depends on orderly and equitable warranty administration. Cost based pricing projects cost experience. Nonconformance with design, manufacturing and performance requirements are determined by:

- * Visual inspection
- * Physical measurement
- * Nondestructive testing
- * Analysis through statistics and simulation

9. Conclusions

A good negotiated warranty at a fair and reasonable price depends on not only the good faith of the parties, but also on their realism and innovation. There is no rule in terms of dollar amount or percentage of contract acquisition cost as to what price should be attached to the warranty. The worth of a warranty should be measured in terms of reliability, maintainability, and availability.

D. SUMMARY

The models presented in this chapter represent only a few of the available warranty pricing approaches. Clearly, no particular pricing algorithm or nonanalytical model can provide the definitive price for each and every warranty situation. Just as no two acquisition contracts are exactly alike, no two warranties should be alike either. Similarities of warranty type can be used to gain insight to pricing estimations, but incontestably each

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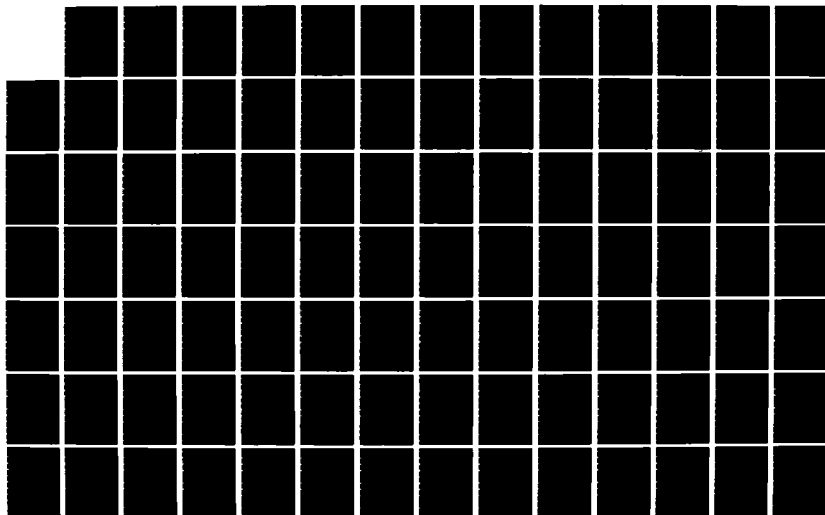
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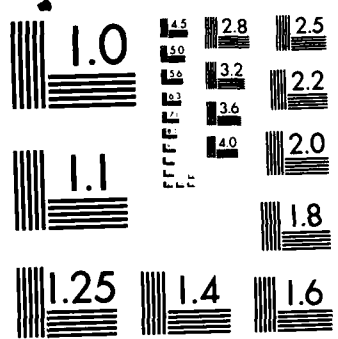
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warranty will have built-in differences which will force alternate evaluations into the pricing equation.

Warranty pricing is the responsibility of both the buyer and the seller. With the passage of Section 794 of the Defense Appropriations Act of 1984, the Government has indicated that the inclusion of warranties in weapons systems acquisitions are absolutely required, and the Government is willing to explicitly pay for them. It will be incumbent on all contractors as well as Government Program Managers to learn how to evaluate warranties and establish a fair price for such coverage since warranty price will become a major section of the contract negotiation process.

The two Blischke and Scheuer models have direct application to the standard commercial aviation warranty. These models would not be suitable for use with the reliability improvement warranty or the mean time between failure warranty since the equations fail to take into account the pricing benefits of improved reliability. The Thomas rebate model could be applied to commercial aviation warranties and other such warranties like the one used with the KC-10 Tanker. This model should not be used with a newly developed platform because it deals with high reliability items which should automatically rule out reliability improvement warranties of any sort. The Thomas prorated rebate model is very similar to the principle presently applied to commercial aviation warranties. Examination of the warranties in Appendices B, C, and D will reveal the prorated formulas used by the commercial companies in their service life policies. The Barton learning curve model seems appropriate to any type of warranty, but seems especially suited to the reliability improvement and the mean time between failure warranties. The success of this model is based on projecting

support costs through reliability improvement in production and repair.

Lastly, the nonanalytic model is presented for the purpose of directing discussion and aiding negotiation for each and every warranty used. The eight step process represents a methodology by which to define each party's obligations and responsibilities in a proposed warranty.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The first objective of this thesis was to examine types of warranties being utilized in the commercial aviation marketplace and what the types of warranties the Department of Defense has used during the aircraft procurement process. The next objective was to determine the generic costs and risks associated with the use of warranties. Finally, several pricing models were studied to develop an understanding of some of the many facets of warranty pricing.

The first conclusion drawn from the research is that one of the reasons that standard commercial aviation warranties are considered to be so successful is that they very specifically define the exact equipment covered, how it is covered, and for how long. The warranty is designed to provide the buyer with reasonable protection, yet very close examination of the warranty shows a significant amount of language that specifically prevents any legal access to any implied warranties as defined in the Uniform Commercial Code. The commercial aviation industry also has the advantage of past history of failure rates and warranty incidents. That is not to say that introduction of a new commercial aircraft model does not have a certain amount of unknowns, but commercial market aircraft generally are of less radically changed design and operate in a better defined environment than military aircraft. Therefore it is this researcher's conclusion that commercial warranties appear to work well because of the ability to price them due to known historical failure rate data, a well-defined operating environment,

and the fact that these warranties are not designed as direct control mechanisms over product performance or improvement.

The second conclusion is that while there are many similarities between commercial aircraft manufacturing and military aircraft manufacturing, respective reliability requirements are not necessarily compatible. Direct across-the-board application of commercial warranties to military aircraft is not appropriate.

Thirdly, no one warranty type can be cost effective for every aircraft procurement. Each transaction between buyer and seller will have some degree of uniqueness and each warranty should be tailored to fit that transaction. Application of a single flat rate or other formula to every procurement would not make the most efficient use of available funds nor would it insure a good business deal.

The fourth conclusion is that cost and risk are not necessarily shared equally between the Government and the contractor. Uniqueness of aircraft type and mission will tend to increase contractor risk since a greater amount of unknowns are entered into the contractor's cost/risk determination. Greater warranty coverage requirements represent higher risk exposure to the contractor, which in turn will result in higher cost to the Government either as a procurement price increase or a directly negotiated line item.

Next, there is no standard pricing model that will work for every situation. Each warranty will need to be evaluated by both the buyer and the seller with the aim of identifying expected cost and anticipated risk so that a fair and reasonable warranty price can be negotiated.

Finally, the use of warranties is going to increase. Congress has mandated warranty use on all weapons systems acquisitions and if this warranty application is successful, it could manifest even more widespread usage on other defense and government acquisitions.

B. RECOMMENDATIONS

The first recommendation is to attempt to reduce the adversarial relationship that often exists between the Government and the contractor. Open discussion and communication are the key to warranty success as may be seen in the relationship of the airlines and commercial aircraft manufacturers. Two things are prerequisite to a successful warranty negotiation. First, the Government must ask for a realistic warranty, be willing to recognize bonafide exclusions, and be willing to reward the contractor for assuming risk. Second, the contractor has to recognize that warranty pricing estimates must be made in good faith and be based on realistic expected costs. Warranties must be fair and equitable to both parties.

It is this researcher's recommendation that a warranty training program be developed and implemented throughout the Department of Defense so that warranties are not inadvertently voided due to inexperienced or knowledgeable actions. This program may entail significant costs, but when weighed against the cost of an invalidated warranty, should prove a wise expenditure in the long run. Training needs to be addressed for every person who will work with the warranty.

Future weapon system acquisitions should be evaluated from two related aspects. The source selection should be based on not only the acquisition price of the system, but also should be based on the cost or benefit of the included warranty. An aircraft bid that is lower than the next

competitor's, but has an inadequate warranty included, is not a good business deal and most certainly does not meet the intent or law of warranty legislation. Contrarily, a low aircraft bid accompanied by a high warranty price may be reasonable, depending on the warranty specifications and the amount of risk the contractor is being asked to assume.

The Department of Defense should develop a handbook or training manual to assist contract personnel in evaluating warranty cost and price. Attention needs to be devoted to establishing methods that will identify key elements of warranty pricing.

Further study should be done to update and develop simpler algorithmic pricing models. Unless the negotiator has detailed knowledge of integral calculus and differential equations, most pricing models will be of very limited value.

Contractors need to develop data bases of warranty incidents. Such data bases can help to identify the warranty costs, which in turn, may be used to project future warranty prices. Regression models should be examined for possible application to warranty pricing problems.

An enforcement board needs to be established to monitor compliance and effectiveness with regard to warranty legislation. If the legislated warranty laws do not achieve the intended weapon system reliability or maintainability, the Department of Defense needs to have the facts available to readdress the pertinent issues with Congress. This board should be made up of personnel of each branch of the armed forces so that no one particular service is dominant and it should direct universal application of warranty legislation.

Finally, the Department of Defense and the commercial aircraft manufacturers need to develop a standard accounting system to allow proper charging of warranty costs.

APPENDIX A

LOCKHEED L-1011 WARRANTY

ARTICLE 7 - WARRANTY

(a) SCOPE OF WARRANTY

(1) Title

Lockheed warrants that the title to each Airplane when conveyed to Buyer shall be good and its transfer rightful. Each Airplane shall upon delivery be free from any security interest or other lien or encumbrance except as expressly agreed upon by the parties.

(2) Specification Conformation

Lockheed warrants that each Airplane shall upon delivery conform to the Specification with the exception of those portions which are stated to be estimates, approximations, or design objectives or which are stated not to be guaranteed by Lockheed.

(3) Design, Material and Workmanship

Lockheed warrants that each Airplane shall upon delivery be free from defect in:

- (i) design predicated on the state-of-the-art at the time of such design;
- (ii) material resulting from defects in (A) the composition or substance of the material, (B) the process of its manufacture, or (C) manufacturing workmanship;
- (iii) workmanship; and
- (iv) installation;

provided that such warranties shall apply only to items manufactured by Lockheed or purchased by Lockheed and manufactured to Lockheed's detail design.

(4) Installation of Purchased Parts

Lockheed's installation of any item purchased by Lockheed and not manufactured to Lockheed's detail design shall conform to the installation instructions of the manufacturer thereof so as not to invalidate the manufacturer's warranty with respect to such item.

(5) Design Information

Detail design information supplied by Lockheed and furnished to Buyer under this ARTICLE 7 for the purpose of repair, rework, or replacement shall be free from defect.

(6) Patent Infringement

Lockheed warrants to Buyer that no Airplane delivered under this Contract shall infringe:

- (i) any United States patent; or
- (ii) any patent issued under the laws of any other country;

excluding any accessories, equipment, or parts not manufactured by Lockheed or to Lockheed's detail design, Buyer-Furnished Equipment, and engines.

(b) REMEDIES

(1) Title

Buyer's remedy for a breach of the warranty set forth in paragraph (a) (1) of this ARTICLE 7, and Lockheed's obligation and liability therefor, shall be determined in accordance with California law. Lockheed shall have a period of thirty (30) days from the notice of the alleged breach to cure the defect by providing Buyer with good title to such Airplane or to otherwise comply with said warranty.

(2) Correction of Defects

(1) Lockheed Correction -

Buyer's remedy for a breach of the warranties set forth in paragraphs (a) (2), (3), (4) and (5) of this ARTICLE 7, and Lockheed's obligation and liability therefor, are expressly limited to repair, rework, replacement or correction of any nonconforming or defective accessory, equipment, or part, or if the defect relates to design information, correction of such information. Any repair, rework, replacement, or correction of any nonconforming or defective accessory, equipment, or part performed by Lockheed pursuant to this ARTICLE 7 shall be promptly completed. In the event that repair, rework, replacement, or correction of a nonconforming or defective accessory, item of equipment, or part is infeasible by reason of the loss, damage, or destruction of the entire Airplane as a result of the nonconformance or defect, Lockheed's sole obligation and liability shall be to pay the Buyer the reasonable cost of repair, rework, replacement, or correction of such accessory, item of equipment, or part as if it had been performed by Lockheed.

(ii) Buyer Correction -

As an alternate to the performance of the work by Lockheed under paragraph (b) (2) (i), Lockheed will, under the conditions set forth below, recognize the performance of the repair, rework or correction of nonconforming or defective items under paragraphs (a) (2), (3) and (4) at Buyer's base repair shops. Lockheed's estimate of the direct manhours reasonable for performance of such repair, rework, or correction, will be the basis for payment or credit to Buyer. The sum of such direct manhours will be multiplied by the Buyer's then current direct labor rate to establish the amount of reimbursement. In the event Lockheed's estimate of such direct manhours is substantially less than Buyer's, the manhours to be used for computation shall be fixed by agreement between Lockheed and Buyer. Lockheed's estimate of such direct manhours shall include the time required for removal, disassembly, reassembly, and reinstallation; however, Buyer shall be compensated for such costs only if the corrective action on the nonconforming or defective item is performed at Buyer's base repair shops.

(iii) Third Party Correction -

Notwithstanding the above, Lockheed agrees that Buyer may utilize the services of a third party for removal of nonconforming or defective items and reinstallation of conforming or nondefective items subject to the following conditions:

- (A) such third party must be acceptable to Lockheed;
- (B) the work is performed by the third party in accordance with Lockheed's approved maintenance procedures; and
- (C) Lockheed's responsibility for reimbursement to Buyer for work performed by the third party will be limited to the amount of reimbursement Lockheed would have paid Buyer had Buyer performed the removal and reinstallation pursuant to paragraph (b) (2) (ii).

(iv) Conditions -

The following conditions apply to work performed by Buyer or third party:

- (A) notification and proof of the defect as stipulated in paragraphs (c) and (e) hereof shall have been provided;
- (B) the work is performed in the manner and to the extent specified by Lockheed;

- (C) the work is of such nature as practically and feasibly permits performance of the work at Buyer's base repair shops or at a third party's facilities; it being further understood that Lockheed shall be liable for any costs for the performance of such repair, rework, or correction only if the nonconformance or defect is determined to be embraced within Lockheed's warranty;
- (D) workmanship, materials and installation furnished by Buyer or a third party are not warranted by Lockheed;
- (E) Lockheed will furnish parts or replacement components, if required, and such information and data as may be required for installation; Lockheed shall have no liability to make payment or to give credit under paragraph (b) (2) (ii) and (b) (2) (iii) unless the work shall have been performed within ninety (90) days after the date of delivery of the parts or component replacements to Buyer or its designated third party, or such longer period as may be agreed upon;
- (F) disposition of replaced items shall be as directed by Lockheed and Lockheed shall be entitled to the benefit of any salvage; and
- (G) pending the determination of whether any warranty liability exists, Lockheed's representative located at Buyer's principal base repair shop shall have the authority to determine on behalf of Lockheed whether the repair, rework, or correction of nonconforming or defective items can be performed by Buyer pursuant to paragraph (b) (2) (ii) or paragraph (b) (2) (iii).

(3) Patent Infringement

(1) Buyer's Remedy -

Buyer's remedy and Lockheed's liability under paragraph (a) (6) above shall be limited to:

- (A) one hundred percent (100%) of all loss, cost, or damage (exclusive of loss of revenue or profit, or cost or damage resulting from loss of use) from infringement of any patent issued under the laws of the United States of America or any other country bound by and entitled to the benefits of Article 27 of the Chicago Convention on International Civil Aviation of December 7, 1944; and
- (B) fifty percent (50%) of such loss, cost, or damage from infringement of the patent of any country not included within subparagraph (A) above in which Buyer is lawfully operating at the time of any actual or alleged infringement.

(11) Conditions -

Buyer's remedy and Lockheed's obligations under this patent infringement warranty are conditioned upon Buyer:

- (A) furnishing to Lockheed written notice within ten (10) days after notice to Buyer of a suit against Buyer alleging infringement, or within thirty (30) days after receipt by Buyer of a written claim of infringement, and promptly furnishing to Lockheed all pertinent data, papers, records, and assistance within Buyer's control;
- (B) making diligent efforts to minimize (other than by nonuse) the loss, cost, or damage for which Lockheed is obligated hereunder and obtaining Lockheed's approval for payment of any claim (except final judgment); and
- (C) authorizing Lockheed to intervene in or control the defense of any related suit and to negotiate, settle, or compromise such claim or suit; provided that, at the request of Buyer, Lockheed will assume and undertake the conduct and control of any such suit where it is practicable to do so.

(c) WARRANTY PERIODS

Lockheed shall have no obligation or liability under this ARTICLE 7 unless it shall have received written notice of an alleged failure to comply with the provisions of paragraph (a) within ninety (90) days after discovery of such failure. In any event, Lockheed's liability under this ARTICLE 7 shall terminate upon expiration of the warranty periods set forth below.

(1) Specification Conformation

With regard to conformance with the Specification under paragraph (a) (2) above, thirty (30) days following the expiration of eighteen (18) months from delivery of each Airplane.

(2) Design, Material, and Workmanship

- (i) With regard to defects in design under paragraph (a) (3) (1) thirty (30) days following the expiration of eighteen (18) months from delivery of each Airplane.
- (ii) With regard to defects in design information under paragraph (a) (5), thirty (30) days following the expiration of one (1) year after delivery of the information to Buyer.

(iii) With regard to defects in material and workmanship under paragraph (a) (3) (ii) and (iii), thirty (30) days following the expiration of two (2) years from delivery of each Airplane; provided, however, that for accessories, equipment or parts not normally inspected within two (2) years, such period shall be thirty (30) days after such inspection or three (3) years after delivery of the Airplane, whichever is earlier.

(3) Installation

With regard to defects in installation under paragraph (a) (3) (iv) and (a) (4), thirty (30) days following the expiration of two (2) years from delivery of each Airplane.

(4) Repaired or Replaced Items

With regard to defects in repaired, reworked, corrected, or replaced accessories, equipment, or parts, thirty (30) days following the expiration of one (1) year from delivery of the repaired, reworked, corrected, or replacement accessory, equipment or part, or for the remainder of period applicable to its original installation in the Airplane as set forth in paragraph (c) (2) or (3) above, whichever expires later.

(d) PURCHASED PARTS

Lockheed has made reasonable efforts to obtain, for the benefit of Buyer, reasonably adequate agreements of indemnification against patent infringement and warranties from the manufacturers of accessories, equipment, or parts purchased by Lockheed and not manufactured to Lockheed's detail design. In the event of any claim asserted by Buyer against any such manufacturer under any such agreement of indemnification against patent infringement or warranty, Lockheed will, at the request of Buyer, take all reasonable action in support of Buyer's claim. Except as to engines, in the event of a default in a warranty obligation assumed by the manufacturer of any item purchased by Lockheed and not manufactured to Lockheed's detail design, with respect to such item, then Lockheed's warranty set forth in paragraph (a) (3) of this ARTICLE 7 shall apply to such item to the same extent as if such item had been manufactured by Lockheed or to its detail design; provided, that if the warranty period available to Buyer under such a manufacturer's warranty is less than the applicable warranty period under this ARTICLE 7, the lesser period shall apply and, provided further, that any rights which Buyer may have against the manufacturer arising from such default shall, at the request of Lockheed, be assigned to Lockheed by Buyer. In the event of a default by the manufacturer of any item purchased by Lockheed and not manufactured to Lockheed's detail design with respect to an indemnification against patent infringement, Lockheed's warranty set forth in paragraph (a) (6) of this ARTICLE 7 shall apply to the same extent as if said item had been

manufactured by Lockheed or to Lockheed's detail design; provided that the conditions set forth in paragraph (b) (3) (ii) of this ARTICLE 7 are satisfied by Buyer. Lockheed will furnish to Buyer, at least thirty (30) days prior to the delivery of the first Airplane, summaries of all such agreements of indemnification against patent infringement and warranties which Lockheed has obtained from such manufacturers.

(e) **CONDITIONS**

Buyer's remedy and Lockheed's obligation and liability therefor under paragraphs (a) (2), (3), (4) and (5) of this ARTICLE 7 are expressly conditioned upon:

(1) Proof of Nonconformance or Defect

Buyer shall submit such proof as may reasonably be required by Lockheed that the asserted nonconformance or defect is due to a matter embraced within said warranty and that it did not result from acts or omissions of Buyer.

(2) Return of Airplane to Lockheed

Lockheed will remove nonconforming or defective items from and install similar conforming or nondefective items in an Airplane; provided Buyer shall have returned such Airplane to Lockheed at Palmdale, California, (or such other reasonable place designated by Lockheed) prior to the expiration of the warranty period set forth in paragraph (c) hereof and have further complied with the obligations set forth in paragraph (c) and this paragraph (e). Buyer shall be responsible for and shall bear all costs associated with the delivery of such Airplane to Lockheed and the return thereof to Buyer. Lockheed's responsibility for the Airplane while it is in Lockheed's possession shall be that of a bailee for hire, and Lockheed shall not be chargeable for loss of use while the Airplane is returned under this provision.

(3) Return of Accessories, Equipment and Parts to Lockheed

Buyer shall deliver to Lockheed at Burbank, California, or at such other place as may be agreed to by Buyer and Lockheed, of any nonconforming or defective accessories, equipment, or parts upon Lockheed's acknowledgment that such alleged nonconformance or defect would be covered by paragraph (a) of this ARTICLE 7, it being agreed that on Lockheed's acknowledgment that such nonconformance or defect is due to a matter embraced within said paragraph (a), Lockheed will pay or credit Buyer the cost of transportation of such item to Lockheed, and Lockheed will bear the cost of transportation of any repaired, reworked or replacement item to Buyer at the place of original shipment by Buyer; provided that Buyer agrees that whenever practical it shall use its own aircraft for any such transportation, at no cost to Lockheed.

(f) LIMITATIONS

(1) Wear and Tear

Normal wear and tear and the need for regular maintenance and overhaul shall not constitute a defect under this warranty.

(2) Disclaimer and Release

LOCKHEED'S WARRANTIES AS SET FORTH IN PARAGRAPH (a) HEREOF ARE EXCLUSIVE, ARE IN LIEU OF, AND BUYER HEREBY WAIVES, ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR OF FITNESS.

The obligations and liabilities undertaken in this ARTICLE 7 are expressly agreed to be the sole obligations and liabilities of Lockheed in the event of a breach of the express warranties made by Lockheed in paragraph (a) hereof. Buyer waives, releases, and renounces all other rights, claims, and remedies against Lockheed under this ARTICLE 7 (including without limitation those with respect to loss of use or other secondary or consequential damage), however occasioned, and whether or not growing out of or based on Lockheed's negligence, actual or imputed.

(3) Negotiated Agreement

Lockheed and Buyer agree that this ARTICLE 7 has been the subject of discussion and negotiation and is fully understood by the parties; that the price of the Airplanes and the other mutual agreements of the parties set forth in this Contract are arrived at in consideration of (a) the express warranties of Lockheed and Buyer's remedies for breach thereof, and (b) the exclusion of and waiver by Buyer of all other warranties, express or implied, and the limitations on remedies. This ARTICLE 7 sets forth the entire agreement of the parties with respect to warranties and the remedy for their breach, and the same may not be modified or amended except by a writing duly signed by the parties to this Contract.

APPENDIX B

BOEING COMPANY WARRANTY

PART A

BOEING WARRANTY

1. Warranties.

Subject to the exceptions set forth in paragraph 2, Boeing warrants that, at the time of delivery, the Aircraft (including all accessories, equipment and parts installed therein) shall:

- (a) conform to the Detail Specification, as it may be changed pursuant to this Agreement, except such portions of the Detail Specification as are stated to be estimates, approximations, design objectives, design criteria or otherwise described as not guaranteed,
- (b) be free from defects in material and workmanship, and
- (c) be free from defects in design in view of the state-of-the-art at the time of design.

2. Exceptions.

The warranties set forth in paragraphs 1(a), 1(b) and 1(c) shall not apply to Buyer Furnished Equipment, nor to Engines (as defined in Exhibit(s) D to this Agreement), nor to any accessory, equipment or part purchased by Boeing that was not manufactured to Boeing's detailed design, except that any defect in the Boeing workmanship incorporated in the installation of such items in the Aircraft, including any failure by Boeing to conform to the installation instructions of the manufacturers of such items that invalidates any applicable warranty from such manufacturers, shall constitute a defect in workmanship for the purposes of this Part A and be covered by the warranty set forth in paragraph 1(b).

3. Survival of Warranties.

With respect to each Aircraft (including accessories, equipment and parts installed therein at the time of delivery), (i) the warranty set forth in paragraph 1(a) shall not survive delivery, and (ii) the warranties set forth in paragraphs 1(b) and 1(c) shall survive delivery only upon the conditions and subject to the limitations set forth in paragraphs 4 through 11 of this Part A.

4. Warranty and Notice Periods.

Buyer's remedy and Boeing's obligation and liability under this Part A, with respect to each defect, are conditioned upon (i) the defect having become apparent to Buyer within the applicable warranty period, and (ii) Boeing's Warranty Administrator at Renton, Washington, having received written notice of the defect from Buyer within 3 months after the defect becomes apparent to Buyer. The warranty periods are:

- (a) As to a defect in material or workmanship, 24 months after delivery of the defective Aircraft, accessory, equipment or part. However, in case of a defect in material or workmanship in an accessory, equipment or part which was installed in an Aircraft at the time of delivery and which has not been inspected by Buyer under Buyer's approved maintenance program prior to the expiration of the above period, the warranty period as to such defect shall be extended to the first to occur of the following:
 - (i) completion of the first inspection applicable to such item under Buyer's approved maintenance program following expiration of the above period, or
 - (ii) expiration of 36 months after delivery of such Aircraft.
- (b) As to a defect in design, 18 months after delivery of the defective Aircraft, accessory, equipment or part.

5. Return and Proof.

Buyer's remedy and Boeing's obligation and liability under this Part A, with respect to each defect, are also conditioned upon:

- (a) the return by Buyer as soon as practicable to Boeing at Boeing's facilities in the Seattle, Washington area, or such other place as may be mutually agreeable, of the Aircraft, accessory, equipment or part claimed to be defective, except when (i) Buyer elects to perform necessary repair or correction of defective accessories, equipment or parts in accordance with the provisions of Part B (Warranty Repairs and Modifications by Buyer) of this Product Assurance Document, or (ii) Buyer elects to scrap non-repairable defective items at Buyer's facilities in accordance with paragraph 8 of this Part A, and

- (b) the submission by Buyer to Boeing's Warranty Administrator at Renton, Washington, of reasonable proof that the claimed defect is due to a matter embraced within the warranty set forth in paragraph 1(b) or 1(c) and that such defect did not result from any act or omission of Buyer, including but not limited to any failure to operate and maintain the Aircraft, accessory, equipment or part involved in accordance with applicable governmental regulations and Boeing's applicable written instructions.

6. Remedies.

Buyer's remedy and Boeing's obligation and liability under this Part A, with respect to each defect, are limited to the following:

- (a) As to a defect in material or workmanship,
 - (i) to the repair of such defect in the accessory, equipment or part in which the defect appears, or, at Boeing's option, to the replacement of such accessory, equipment or part with a similar item free from defect, and
 - (ii) as to any item repaired by Boeing or furnished as a replacement by Boeing pursuant to (i), to the repair or replacement of such item for any further defect in material or workmanship, provided:
 - (1) such further defect becomes apparent to Buyer within any unexpired remainder of the warranty period specified in paragraph 4(a) computed from the initial delivery of the item repaired or replaced pursuant to (i), and
 - (2) Boeing's Warranty Administrator at Renton, Washington, receives written notice of such further defect from Buyer within 3 months after it becomes apparent to Buyer.
- (b) As to a defect in design,
 - (i) to the correction of such defect in the accessory, equipment or part in which the defect appears, and

- (ii) as to any item corrected by Boeing pursuant to (i), to the correction of any further defect in design in such item, provided:
 - (1) such further defect becomes apparent to Buyer within 18 months after delivery of the corrected item or materials required to correct such item, and
 - (2) Boeing's Warranty Administrator at Renton, Washington, receives written notice of such further defect from Buyer within 3 months after it becomes apparent to Buyer.

7. Returned Items.

The following provisions shall apply with respect to each Aircraft, accessory, equipment or part returned to Boeing's facilities pursuant to paragraph 5 of this Part A, or to such other place as may be mutually agreeable:

- (a) All repairs, replacements and corrections described in paragraphs 6(a) and 6(b) shall be performed by or for Boeing at Boeing's expense with reasonable care and dispatch in order that the Aircraft, accessory, equipment or part involved will not be kept out of service longer than necessary.
- (b) The freight charge for shipment from Buyer to Boeing, or to such other place as may be mutually agreeable, of any accessory, equipment or part claimed to be defective shall be paid by Buyer. The freight charge for the return shipment to Buyer of any accessory, equipment or part which has been repaired, replaced or corrected pursuant to this Part A shall be paid by Boeing. Return of any Aircraft by Buyer to Boeing and such Aircraft's return to Buyer's facilities shall be at Buyer's expense.
- (c) Title to and risk of loss of any Aircraft, accessory, equipment or part returned by Buyer to Boeing shall at all times remain with Buyer, except title to and risk of loss of a returned accessory, equipment or part shall pass to Boeing concurrently with shipment by Boeing to Buyer of any item furnished by Boeing to Buyer as a replacement therefor. Upon Boeing's shipment to Buyer of any replacement accessory, equipment or part provided by Boeing pursuant to this Part A, title to and risk of loss of such accessory, equipment or part shall pass to Buyer. (Under this

paragraph 7(c), the party which has risk of loss with respect to any Aircraft, accessory, equipment or part shall have the responsibility of providing any insurance coverage thereon desired by such party.) Boeing shall have only such responsibility for any returned Aircraft, and for any returned accessory, equipment or part so long as Buyer has title thereto, as is chargeable by law to a bailee for hire, but shall not be chargeable for loss of use.

8. Non-Repairable Items.

Buyer may scrap any defective non-repairable accessory, equipment or part at Buyer's facility, provided that an authorized Boeing Customer Support Representative has confirmed such item is non-repairable. Buyer's claim for any accessory, equipment or part to replace such scrapped item shall contain the stamp and signature of Boeing's Customer Support Representative. Such scrapped item shall be processed by Buyer in accordance with the provisions of paragraph 6 of Part B of this Product Assurance Document.

9. Wear and Tear.

Normal wear and tear and the need for regular maintenance and overhaul shall not constitute a defect under this warranty.

10. DISCLAIMER AND RELEASE.

THE WARRANTIES, OBLIGATIONS AND LIABILITIES OF BOEING AND REMEDIES OF BUYER SET FORTH IN THIS PART A ARE EXCLUSIVE AND IN SUBSTITUTION FOR, AND BUYER HEREBY WAIVES, RELEASES AND RENOUNCES ALL OTHER WARRANTIES, OBLIGATIONS AND LIABILITIES OF BOEING AND ANY ASSIGNEE OF BOEING AND RIGHTS, CLAIMS AND REMEDIES OF BUYER AGAINST BOEING OR ANY ASSIGNEE OF BOEING, EXPRESS OR IMPLIED, ARISING BY LAW OR OTHERWISE, WITH RESPECT TO ANY NONCONFORMANCE OR DEFECT IN ANY AIRCRAFT OR OTHER THING DELIVERED UNDER THIS AGREEMENT, INCLUDING BUT NOT LIMITED TO (A) ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS, (B) ANY IMPLIED WARRANTY ARISING FROM COURSE OF PERFORMANCE, COURSE OF DEALING OR USAGE OF TRADE, (C) ANY OBLIGATION, LIABILITY, RIGHT, CLAIM OR REMEDY IN TORT, WHETHER OR NOT ARISING FROM THE NEGLIGENCE OF BOEING OR ANY ASSIGNEE OF BOEING, ACTUAL OR IMPUTED, AND (D) ANY OBLIGATION, LIABILITY, RIGHT, CLAIM OR REMEDY FOR LOSS OF OR DAMAGE TO ANY AIRCRAFT, FOR LOSS OF USE, REVENUE OR PROFIT WITH RESPECT TO ANY AIRCRAFT, OR FOR ANY OTHER DIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES.

11. Negotiated Agreement.

Buyer and Boeing agree that this Part A has been the subject of discussion and negotiation and is fully understood by the parties, and that the price of the Aircraft and the other mutual agreements of the parties set forth in this Agreement were arrived at in consideration of the provisions of this Part A, specifically including the waiver, release and renunciation by Buyer set forth in paragraph 10.

PART B

WARRANTY REPAIRS AND MODIFICATIONS BY BUYER

1. General.

To expedite the return to service of defective accessories, equipment and parts that Boeing is obligated to repair or correct under Part A (Boeing Warranty) of this Product Assurance Document, Boeing and Buyer agree that such repairs and corrections may, at Buyer's option, be performed by Buyer, subject, however, to the provisions of this Part B.

2. Scope.

This Part shall apply only to accessories, equipment and parts manufactured to Boeing's detailed design. This Part is further limited to such repairs and corrections as Boeing would otherwise be obligated to perform under paragraph 6(a) or 6(b) of Part A of this Product Assurance Document, and is subject to the warranty and notice periods and all other conditions and limitations set forth in such Part A, except that defective items need not be returned to Boeing.

3. Repairs and Modifications.

All repairs and modifications shall be performed in accordance with Boeing's applicable written instructions, using such modification kits and other parts and materials as may be furnished by Boeing.

4. Reimbursement.

Upon receipt of Buyer's claim for reimbursement, in accordance with paragraph 5, with respect to any repair or modification within the scope of this Part B, Boeing shall reimburse Buyer as follows:

(a) Direct Labor.

At the warranty labor rate specified in paragraph 4(c) for all direct labor hours reasonably expended by Buyer's direct labor employees in performing the repair or modification, but not to exceed Boeing's reasonable estimate of the manhours required for the

performance thereof by Buyer including, with respect to modifications accomplished in accordance with Boeing's service bulletin instructions, disassembly, removal, installation and reassembly, but excluding time for testing and excluding, with respect to component repairs normally covered under the material and workmanship provisions of Part A of this Product Assurance Document, removal, installation, testing and overhaul time.

(b) Direct Materials.

At the invoice cost thereof to Buyer, excluding any allowances for handling, overhead or the like, for all direct materials incorporated in the repair or modification, excluding any materials used for overhaul, and also excluding such modification kits, parts and materials as may be furnished by Boeing at no charge.

(c) Warranty Labor Rate.

For the purposes of this Part B, the warranty labor rate shall be \$+ per hour or 150% of Buyer's average direct hourly labor rate, whichever is greater. For this purpose, "average direct hourly labor rate" means the average hourly rate (excluding all fringe benefits, premium time allowances, social charges, business taxes and the like) paid to Buyer's employees whose jobs are directly related to the performance of the repair or modification. Prior to or concurrent with submittal of Buyer's first claim for labor reimbursement hereunder, Buyer shall notify Boeing of Buyer's then-current average direct hourly labor rate, and thereafter Buyer shall promptly notify Boeing of any material change in such rate. If requested, Buyer shall furnish to Boeing such data as may be reasonably required to substantiate such rate.

(d) Limitation.

Notwithstanding the foregoing, the total reimbursement with respect to any repair or modification shall not exceed 65% of Boeing's then current sales price for the accessory, equipment or part involved.

5. Claims for Reimbursement.

Unless otherwise agreed in writing, Buyer's claim for reimbursement with respect to any repair or modification must be submitted in writing to Boeing's Warranty Administrator at Renton, Washington, promptly after completion of the repair or modification. All claims for reimbursement shall include the following:

- (a) The identity of the accessory, equipment or part involved, including Boeing part number, serial number, nomenclature and the quantity claimed to be defective.
- (b) The identity of the Aircraft from which each accessory, equipment or part was removed.
- (c) Date the claimed defect became apparent to Buyer.
- (d) Description of the claimed defect and circumstances.
- (e) Date repair or modification completed by Buyer.
- (f) Itemized account of the direct labor hours expended in performing the repair or modification.
- (g) Itemized account of the direct materials incorporated in the repair or modification.

All claims for reimbursement shall be subject to audit by Boeing. Boeing shall promptly notify Buyer of Boeing's disposition of each claim submitted hereunder.

6. Replaced Parts.

In the event component parts of any assembly are replaced by Buyer, the replaced parts shall be tagged with the assembly part number, serial number and warranty claim number and retained for a period of 60 days after submission of Buyer's claim for reimbursement. Such parts shall be made available for Boeing's inspection, upon request, in the event further analysis is required. Such parts may be scrapped if no inspection is requested by Boeing within such 60-day period.

PART C

BOEING SERVICE LIFE POLICY (Models 727/737/747SR)

This Part C defines Boeing's Service Life Policy ("Policy" herein) applicable to the Aircraft.

1. Service Life Policy.

Should a Failure occur in any Covered Component within the following periods:

- (a) as to any Airframe Component or Landing Gear Component, within 10 years after delivery of the Aircraft on which such Component was initially installed; or
- (b) as to any Spare Component, within 10 years after delivery of such Component, or within 10 years after delivery by Boeing of the last new Model /727/ /737/ /747SR/ aircraft to Buyer, whichever first expires,

Boeing shall, at the price provided herein and as promptly as practicable, either (i) design and furnish to Buyer a correction for such Failed Component, including any parts required for such correction (including Boeing designed standard parts but excluding Industry standard parts such as MS and NAS standards), or (ii) furnish to Buyer a replacement Covered Component for such Failed Component.

2. Definitions.

For the purpose of this Policy, the following definitions shall apply:

- (a) "Airframe Component" means any of the primary structural elements specified in Exhibit A attached hereto of the wing, fuselage, or vertical or horizontal tail installed in an Aircraft at the time of delivery.
- (b) "Landing Gear Component" means any of the primary structural elements specified in Exhibit B attached hereto of the landing gear installed in an Aircraft at the time of delivery.

- (c) "Spare Component" means any airframe element specified in Exhibit A or landing gear element specified in Exhibit B that was furnished to Buyer by Boeing as a correction or replacement under this Policy or that was purchased by Buyer from Boeing as a spare part.
- (d) "Covered Component" means an Airframe Component, Landing Gear Component or Spare Component.
- (e) "Failure" means any breakage or defect in a Covered Component.
- (f) "Failed Component" means a Covered Component in which a Failure has occurred.

3. Price.

Any Covered Component or part that Boeing is required to furnish to Buyer under this Policy in connection with correction or replacement of a Failed Component shall be furnished to Buyer at a price determined in accordance with the following formula:

$$P = \frac{CT}{120}$$

P = Price to Buyer.

C = The Boeing then-current spare parts sales price.

T = The total age in months (to the nearest month) of the Failed Component from the date of delivery of the Failed Component to the date of the correction or replacement.

4. Conditions and Limitations.

- (a) Buyer shall, at Boeing's expense, return to Boeing, if return is practicable, any Failed Component that Boeing desires for redesigning studies.
- (b) Installation of any Covered Component corrections or replacements furnished by Boeing under this Policy shall be at Buyer's expense. If installation of such corrections or replacements is performed by Boeing at Buyer's request, the rates charged Buyer for such installation shall not exceed the rates charged other commercial customers of Boeing during substantially the same time period.

- (c) Boeing's obligation under this Policy, with respect to each Failure, is conditioned upon
- (i) Boeing's Warranty Administrator at Renton, Washington, having received written notice of the Failure from Buyer within 3 months after it became apparent to Buyer;
 - (ii) the Failed Component and the aircraft in which it was at any time installed having been serviced and maintained on a scheduled basis in accordance with recognized standards for scheduled air passenger carriers subject to regulation by the Federal Aviation Administration; and
 - (iii) the submission by Buyer to Boeing of reasonable proof that the Failure in any Covered Component is embraced within the scope of this Policy and that such Failure did not result as a consequence of any breakage or defect in any other Aircraft part or component or from any other extrinsic force, or from any act or omission of Buyer, including but not limited to any failure to operate and maintain an Aircraft in accordance with applicable governmental regulations and Boeing's applicable service bulletins, maintenance manuals, overhaul manuals, and written instructions.
- (d) Nothing in this Policy shall be construed as a warranty or representation as to the time an Aircraft or any Covered Component will operate without a Failure, or as an agreement to modify the Aircraft or any Covered Component to conform to new developments in the state of design or manufacturing art. Boeing's sole obligation hereunder is to furnish corrections or replacements for Failed Components as provided in this Policy. Buyer's sole remedy and relief for the nonperformance of any obligation or liability of Boeing arising under or by virtue of this Policy shall be in monetary damages, limited to the amount Buyer reasonably expends in procuring a correction or replacement for any Covered Component which is the subject of a Failure covered by this Policy and to which such nonperformance relates. Buyer hereby waives, releases and renounces all other obligations and liabilities of Boeing, or any assignee of Boeing, and all other rights, remedies and claims, including all claims for damages, direct, incidental or consequential, of Buyer against Boeing, or any assignee of Boeing, express or implied, arising by law or otherwise, with respect to matters arising under or by virtue of this Policy.

Body (Continued)

- (e) Main gear wheel wells, ceiling and bulkheads.
- (f) Floor beams in the control cab and passenger cabin area, excluding seat tracks in both areas.
- (g) Pressure bulkhead at Station 1183 and the pressure bulkhead at Station 178.
- (h) Keel beam and breather web between FS bulkhead and B.S. 950, including splices.
- (i) Bulkheads at Stations 178, 259, 294, 351, wing front and rear spar support bulkheads, 950, 1183 and 1343 excluding all system components and related installation and connecting devices, insulation, lining, and decorative panels and related installation and connecting devices.
- (j) Engine strut support fittings attached directly to body bulkhead.

Vertical Tail

- (a) Front and rear stabilizer attachment fittings and pins.
- (b) Stabilizer jack screw support fitting.
- (c) Stabilizer hinge support fittings at Station 1343, but not including the bearing.
- (d) External skins between front and rear spars.
- (e) Front and rear spar chords, webs and stiffeners.
- (f) Inspar ribs.
- (g) Support structure in the vertical fin for rudder hinges and actuators.
- (h) Rudder internal, fixed attachment and actuator support structure.

Horizontal Tail

- (a) External skins between front and rear spars.
- (b) Front and rear spar chords, webs and stiffeners.

Horizontal Tail (Continued)

- (c) Inspar ribs.
- (d) Stabilizer hinge support structure.
- (e) Stabilizer screw support structure.
- (f) Stabilizer center section and fittings splicing to outboard stabilizer.
- (g) Support structure in the horizontal tail for the elevator hinges, reaction links and actuators.
- (h) Elevator internal, fixed attachment and actuator support structure.

NOTE: The Service Life Policy does not cover any bearings, bolts, bushings, clamps, brackets, actuating mechanisms or latching mechanisms used in or on the Covered Components.

LANDING GEAR COMPONENTS

[727]

Main Gear

- (a) Outer cylinder.
- (b) Inner cylinder.
- (c) Trunnion link.
- (d) Side strut.
- (e) Drag strut.
- (f) Orifice support tube.

Nose Gear

- (a) Outer cylinder.
- (b) Inner cylinder.
- (c) Orifice support tube.

NOTE: The Service Life Policy does not cover any bearings, bolts, bushings, clamps, brackets, actuating mechanisms or latching mechanisms used in or on the Covered Components.

AIRFRAME COMPONENTS

[727]

Wing

- (a) Upper and lower wing skins and stiffeners.
- (b) Wing spar webs, chords and stiffeners.
- (c) Inspar wing ribs.
- (d) Inspar splice plates and fittings.
- (e) Forward and aft main landing gear trunnion support structure.
- (f) Wing center section floor beams, lower beams and spanwise beams, but not the seat tracks attached to floor beams.
- (g) Front and rear spar wing-to-body attach fittings and pins.
- (h) Support structure in the wing for spoilers and spoiler actuators, aileron hinges and reaction links, and for leading and trailing edge flaps.
- (i) Trailing edge flap tracks and carriages.
- (j) Aileron and trailing edge flap internal, fixed attachment and actuator support structure.

Body

- (a) External surface skins and doublers, longitudinal stiffeners, circumferential rings and frames, between Body Stations 178 and 1342, excluding all system components and related installation and connecting devices, insulation, lining, and decorative panels and related installation and connecting devices.
- (b) Window and windshield structure but excluding the windows and windshields.
- (c) Sills and frames around body openings for the entry, galley and cargo doors and the escape hatches.
- (d) Nose wheel well structure, including the wheel well walls, ceiling, forward and aft bulkheads, and the gear support structure.

PART E

SUPPLIER WARRANTIES AND PATENT INDEMNITIES

1. Supplier Warranties and Supplier Patent Indemnities.

Boeing shall use diligent efforts to obtain from manufacturers of accessories, equipment and parts installed in the Aircraft at the time of delivery that were purchased by Boeing but were not manufactured to Boeing's detailed design (other than Engines, as defined in Exhibit(s) D to this Agreement), adequate warranties and indemnities against patent infringement enforceable by Buyer (Supplier Warranties). Boeing shall furnish copies of the Supplier Warranties to Buyer prior to delivery of the first Aircraft. (The commitments of the Engine manufacturer regarding warranties and indemnities against patent infringement shall be as set forth in Part F of this Product Assurance Document.)

2. Boeing Assistance in Administration of Supplier Warranties.

In the event Buyer experiences any problem in the administration of any claims Buyer may have initiated under the Supplier Warranties obtained by Boeing pursuant to paragraph 1, and Buyer submits to Boeing's Warranty Administrator at Renton, Washington, such information and data in its possession as may be reasonably required by Boeing to investigate any such problem, then Boeing shall promptly conduct an investigation of such problem and shall assist Buyer in the administration of any claims Buyer may have under such Supplier Warranties.

3. Boeing Support in Event of Supplier Default.

In the event that:

- (a) any manufacturer, under any Supplier Warranty obtained by Boeing pursuant to paragraph 1, defaults in the performance of any material obligation contained in such Supplier Warranty with respect to a defect in material or workmanship or a defect in design in any accessory, equipment or part installed in the Aircraft at the time of delivery, and
- (b) Buyer submits to Boeing's Warranty Administrator at Renton, Washington, reasonable proof that such default has occurred,

then the warranty set forth in paragraph 1(b) and 1(c), as the case may be, of Part A (Boeing Warranty) of this Product Assurance Document, and paragraphs 3 through 11 of such Part A, shall apply to such defect to the same extent as if such accessory, equipment or part had been manufactured to Boeing's detailed design, except that:

- (i) the warranty period with respect to such accessory, equipment or part shall be the longer of the applicable period set forth in such Supplier Warranty, if a warranty period is expressly set forth therein, or the applicable period set forth in paragraph 4 of Part A of this Product Assurance Document,
- (ii) the notice period set forth in paragraph 4 of Part A shall be 3 months after the occurrence of such default.

At Boeing's request, Buyer shall assign to Boeing, and Boeing shall be subrogated to, any of Buyer's rights against such manufacturer as Boeing may reasonably require in the fulfillment of its obligations hereunder.

[P&W]

[3D and 9D-7A]

PART F

ENGINE MANUFACTURER'S WARRANTY

[JT3D/JT9D-7A]

Boeing has obtained from United Technologies Corporation ("United") the right to extend to Buyer the provisions of United's standard sales warranty subject, however, to Buyer's acceptance of the conditions set forth in such warranty. Accordingly, Boeing hereby extends to Buyer, and Buyer hereby accepts, the provisions of United's sales warranty hereinafter set forth and such warranty shall apply to turbine engines installed in the Aircraft at the time of delivery; provided that Buyer may, by notice given to Boeing and United, prior to delivery of the Aircraft, elect to substitute for such sales warranty any corresponding warranty included either in a General Terms Agreement currently effective between Buyer and United or in a contract for the sale by United to Buyer of turbine engines. In consideration for such extension, Buyer hereby releases and discharges Boeing and United from any and all claims, obligations and liabilities whatsoever arising out of the purchase or use of said installed turbine engines except as expressly assumed by United in such warranty.

UNITED TECHNOLOGIES CORPORATION
WARRANTIES, REMEDIES AND LIMITATIONS

1. Defective Goods.

United Technologies Corporation, Pratt & Whitney Aircraft Group, Commercial Products Division (Seller) warrants to Buyer that at the time of delivery the goods sold by Seller will be free from defects in material and manufacture and will conform substantially to Seller's applicable specifications. Seller's liability and Buyer's remedy under this warranty are limited to the repair or replacement, at Seller's election, of goods or parts thereof returned to Seller which are shown to Seller's reasonable satisfaction to have been defective; provided that written notice of the defect shall have been given by Buyer to Seller within 90 days after the first operation or use of the goods (or if the goods are installed in new aircraft, within 90 days after acceptance of such aircraft by the operator of each new aircraft) but in no event later than one year after the date of delivery of such goods by Seller. Transportation charges for the return of defective goods to Seller and their reshipment to Buyer and the risk of loss thereof will be borne by Seller only if returned in accordance with written shipping instructions from Seller.

[P&W]

[3D and 9D-7A]

2. Title.

Seller warrants to Buyer that it will convey good title to the goods it sells. Seller's liability and Buyer's remedy under this warranty are limited to the removal of any title defect or, at the election of the Seller, to the replacement of the goods or parts thereof which are defective in title; provided, however, that the rights and remedies of the parties with respect to patent infringement shall be limited to the provisions of subparagraph 3 below.

3. Patent Infringement.

Seller shall conduct, at its own expense, the entire defense of any claim, suit or action alleging that, not as a result of further combination (other than (A) combination with other Products delivered to Buyer by Seller and (B) as to engines, combination with the airframe in which they are installed), the use or resale by Buyer or any subsequent purchaser or user of the goods sold by Seller directly infringes any United States patent but only on the conditions that (1) Seller receives prompt written notice of such claim, suit or action and full opportunity and authority to assume the sole defense thereof, including settlement and appeals, and all information available to Buyer and defendant for such defense; (2) said Products are made according to a specification or design furnished by Seller; and (3) the claim, suit or action is brought against Buyer or one expressly indemnified by Buyer. Provided all of the foregoing conditions have been met, Seller shall, at its own expense, either settle said claim, suit or action or shall pay all damages, excluding consequential damages, and costs awarded by the court therein and, if the use or resale of such Products is finally enjoined, Seller shall, at Seller's option, (i) procure for defendant the right to use or resell the Products, (ii) replace them with equivalent noninfringing Products, (iii) modify them so they become noninfringing but equivalent or (iv) with Buyer's consent remove them and refund the purchase price (less a reasonable allowance for use, damage and obsolescence). If a claim, suit or action for infringement is based on a detailed design or specification furnished by Buyer or on the use or resale of the goods sold by Seller in a combination not within the scope of the foregoing indemnity, Buyer shall indemnify and save Seller harmless therefrom.

[P&W]

[3D and 9D-7A]

4. Engine Parts Service Policy.

Seller warrants to Buyer that it will extend to Buyer, with respect to aircraft engines of Seller's Pratt & Whitney Aircraft Division sold to Buyer, service allowances and adjustments in accordance with the applicable Engine Parts Service Policy offered by said Division on the date of Seller's receipt of the order therefor. Seller's liability and Buyer's remedy under this warranty are limited to the service allowances and adjustments and are subject to the general conditions stipulated in the applicable Engine Parts Service Policy; provided, however, that no change in or retraction of such Policy shall apply to engines delivered or to be delivered by Seller under orders received by Seller prior to Seller's announcement of any such change or retraction.

5. Limitation.

THE FOREGOING WARRANTIES ARE EXCLUSIVE AND ARE GIVEN AND ACCEPTED IN LIEU OF ANY AND ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION THE IMPLIED WARRANTY OF MERCHANTABILITY. THE REMEDIES OF THE BUYER FOR ANY BREACH OF WARRANTY SHALL BE LIMITED TO THOSE PROVIDED HEREIN TO THE EXCLUSION OF ANY AND ALL OTHER REMEDIES INCLUDING, WITHOUT LIMITATION, INCIDENTAL OR CONSEQUENTIAL DAMAGES. NO AGREEMENT VARYING OR EXTENDING THE FOREGOING WARRANTIES, REMEDIES OR THIS LIMITATION WILL BE BINDING UPON SELLER UNLESS IN WRITING, SIGNED BY A DULY AUTHORIZED OFFICER OF SELLER.

PART G

BOEING INTERFACE COMMITMENT

1. Interface Problems.

If Buyer experiences any technical problem in the operation of the Aircraft or its systems due to malfunction or failure of an accessory, equipment, or part the cause of which, after due and reasonable investigation, is not readily identifiable by Buyer, but which Buyer reasonably believes to be attributable to the design characteristics of one or more components of the Aircraft (an "Interface Problem"), Boeing shall, if requested by Buyer, and without additional charge to Buyer, promptly conduct an investigation and analysis of such Interface Problem to determine, if possible, the cause or causes of the Interface Problem and to recommend such corrective action as may be feasible. Buyer shall furnish to Boeing all data and information in Buyer's possession relevant to the Interface Problem, and shall cooperate with Boeing in the conduct of its investigations and such tests as may be required. Boeing shall promptly advise Buyer in writing at the conclusion of its investigation of Boeing's opinion as to the cause or causes of the Interface Problem and Boeing's recommendation as to corrective action.

2. Boeing Responsibility.

If Boeing determines that the Interface Problem is primarily attributable to the design of any component manufactured to Boeing's detailed design, Boeing shall, if requested by Buyer, correct the design of such component to the extent of any then existing obligations of Boeing under Part A (Boeing Warranty) or Part C (Boeing Service Life Policy) of this Product Assurance Document.

3. Supplier Responsibility.

If Boeing determines that the Interface Problem is primarily attributable to the design of a component not manufactured to Boeing's detailed design, Boeing shall if requested by Buyer, reasonably assist Buyer in processing any warranty claim Buyer may have against the manufacturer of such component. Boeing shall also take whatever reasonable action is permitted by its contracts with such manufacturer in an effort to obtain a correction of the Interface Problem acceptable to Buyer.

4. Joint Responsibility.

If Boeing determines that the Interface Problem is partially attributable to the design of a component manufactured to Boeing's detailed design and partially to the design of components not manufactured to Boeing's detailed design, Boeing shall, if requested by Buyer, seek a solution to the Interface Problem through the cooperative efforts of Boeing and the manufacturers of the other component involved. Boeing shall promptly advise Buyer of such corrective actions as may be proposed by Boeing and such other manufacturers; such proposal to be consistent with any then existing obligations of Boeing and such other manufacturers. If such proposal is acceptable to Buyer, the proposed action shall be taken. Acceptance by Buyer of such action shall constitute full satisfaction of any claim Buyer may have against either Boeing or such other manufacturers with respect to such Interface Problem.

5. General.

- (a) All requests under this Part G shall be directed to Boeing's Warranty Administrator at Renton, Washington.
- (b) All reports, recommendations, data and other documents furnished by Boeing to Buyer pursuant to this Part G shall be deemed to be things delivered under this Agreement and shall be subject to the disclaimer and limitations set forth in paragraph 10 of Part A (Boeing Warranty) of this Product Assurance Document.
- (c) At Boeing's request, Buyer shall assign to Boeing, and Boeing shall be subrogated to, any of Buyer's rights against any Supplier as Boeing may reasonably require in the fulfillment of its obligations hereunder.

APPENDIX C

MCDONNELL DOUGLAS MD-80 WARRANTY

I. WARRANTY AND SERVICE LIFE POLICY

A. SELLER'S WARRANTY

1. Coverage - Subject to stated limitations and conditions, Seller warrants that the aircraft structure, systems, accessories, equipment and parts of the aircraft whether installed on the aircraft or as spare or replacement parts (hereinafter referred to as "Products") if made to detailed design and detailed specifications originated by Seller shall, at the time of delivery by Seller, be free from:
 - a. Defects in material and workmanship;
 - b. Defects caused by installation by Seller of any article not manufactured by Seller in a manner not in accordance with the reasonable instructions of the manufacturer;
 - c. Defects inherent in the design, including defects arising from selection by Seller of materials or process of manufacture, in view of the state of the art as of the date of such design; and
 - d. Defects arising from failure to conform to the Detail Specification (Exhibit "A" of the Purchase Agreement), except as to portions thereof stated to be estimates or approximations or stated to be design objectives.
2. Term - Defects as defined in paragraph 1. above must become apparent to Buyer:
 - a. As to defects defined only in subparagraphs a., b. and d. of paragraph 1. above, within twenty-four (24)

months after delivery of each Product; provided, however, in the case of any defects in material and workmanship in any Products installed in an aircraft at the time of delivery which have not been inspected by Buyer under its established maintenance program prior to the expiration of such twenty-four (24) month period, such defects must have become apparent and Buyer must have notified Seller thereof within one (1) month after completion of the first applicable inspection or within thirty-six (36) months, whichever shall first expire after delivery of each Product;

b. As to defects in subparagraph l.c. above, whether or not also constituting a defect under subparagraphs a., b. or d. of paragraph l. above, within eighteen (18) months after delivery of each Product.

3. Repair or Replacement - The extent of Seller's liability under this warranty as to defects in material or workmanship, defects arising from the selection of material or the process of manufacture, defects caused by faulty installation and such defects arising from such failure to conform to the Detail Specification is limited to the repair of such defects in any Product or, at Seller's election where applicable, to the repair or replacement (with a similar item free from the defect in question) of any Product which is defective in any of such respects.

4. Correction of Design Defects - The extent of Seller's liability under this warranty as to defects inherent in the design is limited to the correction at its expense of all such defects in the Product which is defective in design. If such design defects become apparent and Buyer gives Seller due and timely notice within the applicable period set forth in subparagraph 11.f. of this Part I.A. and Seller is obligated to correct such defect, Seller shall also make such correction in any Product which shall not have been delivered to Buyer. Seller, however, shall not be responsible nor deemed to be in default on account of any delays in performance due to any such corrections. Also, rather than accept a delay in delivery, Buyer may elect to accept delivery and subsequently file a claim for a warranty correction as though the defect had become apparent immediately after delivery.

5. Timely Corrections - Seller, or Buyer with the approval of Seller, shall make the repairs, replacements and corrections with reasonable care and dispatch in order that the Product involved may not be kept out of service longer than necessary.

6. Seller's Approval - Seller shall, within one-half (1/2) month following receipt of Buyer's notice of a defect accompanied by Buyer's request that it be permitted to make a repair, replacement or correction, notify Buyer of approval or

disapproval of the request. Failing timely notice by Seller, approval of the request shall be deemed to have been given by Seller.

7. Labor Reimbursement - Should Buyer be permitted to make any of the repairs, replacements and corrections, Seller shall establish a "standard" for the labor hours to repair the defect and will reimburse Buyer for the "standard" hours or for Buyer's actual labor hours to repair the defect, whichever is less. Buyer's warranty labor rate shall be based upon Buyer's direct labor rate per man-hour, subject to annual review and adjustment as mutually agreed to between Buyer and Seller. In no event, however, shall the amount exceed the applicable manufacturing direct labor rate of the Douglas Aircraft Company, plus a burden rate of one hundred percent (100%) of the manufacturing rate.

8. Labor Coverage - Buyer's disassembly of the aircraft to correct the defects, removal of the defective or faulty Products and installation of the corrected or new Products and reassembly of the aircraft shall be at Buyer's expense. (When temporary or interim repairs, replacements and corrections are accomplished by Buyer and not proposed or requested by Seller, Seller's liability to Buyer shall not exceed the furnishing of a permanent repair, replacement or correction or its monetary equivalent.)

9. Claims Information - Buyer's claim for reimbursement with respect to any repair or modification must be submitted in writing to Seller's Warranty Administrator at Long Beach, California, promptly after completion of the repair or modification. All claims for reimbursement shall include the following:

- a. The identity of the Product involved, including Seller's part number, nomenclature and the quantity claimed to be defective.
- b. The identity of the aircraft from which each Product was removed.
- c. Total flight hours accrued on each Product at the time the claimed defect became apparent to Buyer.
- d. Date the claimed defect became apparent to Buyer.
- e. Description of the claimed defect and circumstances.
- f. Date repair or modification completed by Buyer.
- g. Itemized account of the direct labor hours expended in performing the repair or modification.
- h. Itemized account of the direct materials incorporated in the repair or modification.

10. Audit, Transportation and Waiver - All claims for reimbursement shall be subject to audit by Seller. Seller shall promptly notify Buyer of Seller's disposition of each claim. All transportation costs of sending defective Products to Seller's factory shall be borne by Buyer. The transportation costs for return to Buyer of the repaired, replaced or corrected Product shall be borne by the Seller. No approval by Seller under this paragraph 10. or paragraph 6. above shall constitute a determination that a defect, in fact, did exist.

11. Limitations - Seller shall, as to each defect, be relieved of all obligation and liability under this warranty if:

a. The aircraft was operated with any Product not specifically approved by Seller unless Buyer furnishes reasonable evidence that such Product was not a cause of the defect;

b. The aircraft was not operated or maintained in accordance with Seller's instructions furnished in the "AIRCRAFT MANUALS AND DOCUMENTATION" unless Buyer furnishes reasonable evidence that such operation or maintenance, as the case may be, was not a cause of the defect;

c. The aircraft was not operated under normal airline use unless Buyer furnishes reasonable evidence that such operation was not a cause of the defect;

d. The aircraft was repaired, altered or modified without Seller's approval or if the aircraft was operated subsequent to involvement in an accident unless Buyer furnishes reasonable evidence that the accident or such repair, alteration, modification or operation after the accident was not a cause of the defect; however, this limitation, insofar as it relates to repairs and accidents, shall not be applicable to operation after minor accidents or to routine repairs or replacements which normally occur in the operation of an aircraft, if such repairs or replacements are made with suitable material and according to reasonable airline engineering and maintenance standards.

e. Buyer does not (i) report the defect in writing or by telegram to Seller's Warranty Administrator at its factory in Long Beach, California, within two (2) months following the end of the applicable period of time specified in paragraph 2. of this paragraph A., or within two (2) months following such defect becoming apparent, whichever is earlier, and (ii) return the defective or faulty Product to said factory (or, if return to Seller's factory is not feasible and Seller so agrees in advance in writing, to Buyer's base repair shop or other appropriate facility in the United States) within two (2) months following the end of the applicable period of time specified in paragraph 2. of this paragraph A., or within two

(2) months following such defect becoming apparent, whichever is earlier, and further, if for reasons beyond Buyer's control, return of the item to Seller's factory is not possible within said two-month period and if Buyer so notifies Seller in writing, the said two-month period will be waived but Buyer must return the item to Seller's said factory if, as and when such return does become feasible;

f. Buyer does not submit reasonable proof to Seller within two (2) months after the defect becomes apparent (except when such period is waived) that the defect is due to a matter embraced within this warranty. Seller shall approve or disapprove Buyer's substantiation of its warranty claim in writing within two (2) months of receipt.

12. Automatic Approval - With respect to matters made the subject of Seller's approval under subparagraphs a. and d. of paragraph 11., Seller's approval or disapproval shall be made in writing to Buyer within two (2) months after Buyer's timely written notice to Seller's Warranty Administrator is received by Seller at its Long Beach plant requesting approval and referring to this paragraph 12. In the event of disapproval, Seller shall set forth the reasons in its statement of disapproval. Seller's failure to deliver to Buyer a written statement of approval or disapproval within such two-month period shall (without extending or increasing

Seller's obligations in any way) constitute approval by Seller of the subject matter of the particular request involved.

13. Normal Usage - Normal wear and tear and the need for regular overhaul shall not constitute a defect or failure under this warranty. Buyer acknowledges that some of the accessories, equipment and parts, though without defects when delivered, have a normal service expectancy and warranty shorter than the periods specified in paragraph 2. of this Part I. as set forth in Seller's manuals and documentation furnished under Part IV.

B. WARRANTIES FROM OTHER MANUFACTURERS AND ENGINE WARRANTY

1. Seller's Efforts - Seller shall make every reasonable effort to obtain warranties (equivalent to Seller's) from other manufacturers, vendors, or suppliers of systems, accessories, equipment and parts supplied in respect to the aircraft and selected by Seller but not manufactured to Seller's detailed design and detailed specifications originated by Seller. These warranties shall either run to Buyer specifically or be assignable by Seller to Buyer. Seller shall make reasonable effort to obtain for Buyer the same warranties, more favorable warranties, or alternate overhaul plans, to encompass Buyer's direct purchase of spare parts. In addition, Seller shall make reasonable effort to obtain for Buyer said other manufacturers', vendors' or suppliers' performance

guarantees, service and product performance guarantees, service and product support policies and data at least as favorable as those obtained by Seller. Seller shall convey to Buyer the nature and extent of such warranties and of the attendant terms and conditions, guarantees, services, policies and data.

2. Engine Warranty - Seller has obtained from United Technologies Corporation, Pratt & Whitney Aircraft Group, Commercial Products Division (UNITED) the right to extend to Buyer the provisions of UNITED's sales warranty, attached hereto as Exhibit "E". Buyer agrees that the warranty applicable to turbine engines installed at the time of delivery in the aircraft to be furnished under this contract shall be the UNITED sales warranty; provided that Buyer may, by notice given to UNITED prior to delivery of the aircraft under this contract, elect to substitute for such sales warranty any corresponding warranty included either in a General Terms Agreement currently effective between the Buyer and UNITED or in a contract for the sale by UNITED to the Buyer of turbine engines intended for use in direct support of the aircraft to be furnished under this contract. Buyer agrees that any such warranty shall be deemed to have been provided directly by UNITED to Buyer. Buyer shall look to UNITED and not Seller with respect to any such warranty and Seller has no obligation under such warranty and does not act as guarantor of UNITED's warranty. In consideration of such extension, Buyer hereby

releases and discharges UNITED from any and all liabilities and obligations whatsoever arising out of the purchase or use of said installed turbine engines, except-as expressly assumed by UNITED in such warranty.

C. SERVICE LIFE POLICY

Seller agrees that should fleetwide or repetitive failure occur in any of the covered components, the provisions of this paragraph C. (hereinafter referred to as "this Policy") shall apply.

1. Definitions - For the purposes of this paragraph C., the following definitions apply:

a. Failure means any breakage of, or defect in, a covered airframe component (exclusive of intergranular corrosion) which has occurred and which can reasonably be expected to occur on a repetitive or fleetwide basis.

b. Covered airframe component means any of the primary structural elements of the wing, fuselage, vertical and horizontal empennage of the aircraft as specified in paragraph 7. below.

2. Term - Should a failure occur in any covered component of an aircraft within ten (10) years after delivery to Buyer regardless of the number of flight hours or cycles, Seller will, at the price provided and as promptly as practicable, either (i) design and furnish to Buyer a correction for such failed covered component and provide any

parts required for such correction (exclusive of standard parts) or (ii) furnish to Buyer a replacement covered component for such failed component for installation of such correction or component by Buyer in such aircraft.

3. Costs - Any part or covered component which Seller is required to furnish to Buyer under this Policy in connection with correction or replacement of a covered component shall be furnished to Buyer at a price determined in accordance with the following formula:

$$P = \frac{CT}{N}$$

where;

P = Price to Buyer;

C = The Seller's then current spare parts sales price;

T = The total time to the nearest month during which the covered component, which is the subject of a failure, has been used, and

N = 120 months.

4. Conditions and Limitations - The following general conditions and limitations shall apply to this paragraph C.

a. The return to Seller, if such return is practicable, of any covered component, which is the subject of a failure, necessary for redesigning studies, shall be at

Buyer's expense. Any required disassembly and reassembly of the aircraft or landing gear, or parts of either, removal of the covered component which is the subject of a failure and reassembly and installation of the corrected or replacement covered component, shall be at Buyer's expense. If such disassembly, reassembly and installation is accomplished by Seller at Buyer's request, the rates to be charged for any such services shall not exceed the rates charged to other commercial customers of Seller during approximately the same time period.

b. Seller's obligations under this Policy are conditioned upon the submission of reasonable proof to Seller that the failure is embraced within the scope of this Policy.

c. In case of failure, Buyer must have reported the breakage or defect in writing or by telegram to Seller's Warranty Administrator at its factory in Long Beach, California, within two (2) months after any breakage or defect in a covered component becomes evident, whether or not said breakage or defect can reasonably be expected to occur in any other aircraft. Omission by Buyer to give this required notice to Seller shall excuse Seller from all obligations with respect to such failure.

d. The provisions of paragraph 11. (except for subparagraphs e. and f. thereof) of paragraph A. of Part I. entitled "Seller's Warranty", are incorporated by this reference and shall condition Seller's obligations under this Policy with respect to any covered component.

e. Seller's obligations under this Policy shall not apply to any aircraft which has not been correctly modified in accordance with Seller's Service Bulletin specifications or instructions furnished by Seller to Buyer prior to the receipt by Seller from Buyer of any notice of an occurrence which constitutes, or which at a later date is shown to constitute, a failure in a covered component.

f. In the event of any breakage or defect in a covered component, if Seller determines that such breakage or defect may not reasonably be expected to occur on a fleetwide or repetitive basis, this Policy shall not apply with respect to such breakage or defect.

5. Coverage - This Policy is neither a warranty, performance guarantee nor an agreement to modify the aircraft or airframe components to conform to new developments occurring in the state of airframe design and manufacturing art. Seller's obligation is to make only those corrections to the airframe components or furnish replacement as provided in this Policy.

6. Assignment - Buyer's rights under this paragraph C. hereof shall not be assigned, sold, leased, transferred or otherwise alienated by operation of law or otherwise, without Seller's prior written consent. Any unauthorized assignment, sale, lease, transfer or other alienation of Buyer's rights under this Policy shall immediately void this Policy in its entirety.

7. Airframe Components - The following specific airframe items are subject to the provisions of paragraph C.1.b:

a. PYLONS

Front engine mount yoke

Spars and spar caps

Engine mount yoke to pylon attach fitting

Upper and lower plating and stiffeners
between spars

Attach angle

b. WINGS

Front and rear spars

Upper and lower stringers and plating
between spars

Landing gear bulkhead and forging

Bulkhead at side of fuselage, including
trapezoidal panel

Flap ribs in the wing

Wing to fuselage attach tee

Wing flap attach fittings

c. FUSELAGE

Frames, plating, stringers and pressure
bulkheads, but excluding all access doors

d. EMPENNAGE

Vertical spars and plating between spars

Aft fuselage vertical stabilizer
carry-through structure
Horizontal stabilizer spars, integral
plating between spars, and pivot fittings

D. GENERAL

1. THE WARRANTY AND SERVICE LIFE POLICY PROVIDED IN THIS PART I. AND THE OBLIGATIONS AND LIABILITIES OF SELLER UNDER SAID WARRANTY AND SERVICE LIFE POLICY ARE EXCLUSIVE AND IN LIEU OF, AND BUYER HEREBY WAIVES, ALL OTHER REMEDIES, WARRANTIES, GUARANTEES OR LIABILITIES, EXPRESS OR IMPLIED, WITH RESPECT TO EACH AIRCRAFT, ARTICLE, PRODUCT, ACCESSORY, EQUIPMENT, PART, SERVICE, MANUAL, DOCUMENT AND DATA DELIVERED UNDER THIS AGREEMENT AND RELATED DOCUMENTS, ARISING BY LAW OR OTHERWISE (INCLUDING, WITHOUT LIMITATION, ANY OBLIGATION OR LIABILITY ARISING FROM NEGLIGENCE OR TORT OR WITH RESPECT TO FITNESS, MERCHANTABILITY, LOSS OF USE, REVENUE OR PROFIT OR CONSEQUENTIAL DAMAGES). THIS WARRANTY OR SERVICE LIFE POLICY SHALL NOT BE EXTENDED, ALTERED OR VARIED, EXCEPT BY A WRITTEN INSTRUMENT SIGNED BY SELLER AND BUYER.

2. BUYER AND SELLER STATE AND AGREE THAT THIS PART I. HAS BEEN THE SUBJECT OF DISCUSSION AND NEGOTIATION AND IS FULLY UNDERSTOOD BY THE PARTIES AND THAT THE PRICE OF THE AIRCRAFT AND THE OTHER MUTUAL AGREEMENTS OF THE PARTIES SET FORTH IN THIS AGREEMENT WERE ARRIVED AT IN CONSIDERATION OF THE PROVISIONS OF THIS PART I., SPECIFICALLY INCLUDING THE WAIVER BY BUYER SET FORTH IN PARAGRAPH D.1. ABOVE.

APPENDIX D

MCDONNELL DOUGLAS KC-10 WARRANTY

38. WARRANTY AND SERVICE LIFE POLICY

Part I - Warranty

a. Subject to the limitations and conditions hereinafter set forth, Contractor warrants that the aircraft structure, systems, accessories, equipment, and all parts of the aircraft, whether installed on the aircraft or as spare or replacement parts, delivered hereunder which have been manufactured by Contractor and by other manufacturers if made to detailed design and detailed specifications originated by Contractor shall, at the time of delivery by Contractor, be free from:

(1) Defects in material and workmanship;

(2) Defects caused by installation by Contractor of any article not manufactured by Contractor in a manner not in accordance with the reasonable instructions of the manufacturer;

(3) Defects inherent in the design thereof, including defects arising from selection by Contractor of materials or process of manufacture, in view of the state of the art of the date of such design; and

(4) Defects arising from failure to conform to the Detail Specification in effect at the time of delivery, except as to portions thereof stated to be estimated or approximations or stated to be design objectives.

b. Defects as defined in paragraph a of this Part I must become apparent to the Government:

(1) As to defects defined only in subparagraphs (1), (2) and (4) of paragraph a of this Part I, within sixty (60) months or five thousand (5,000) flying hours, whichever first expires after delivery of each aircraft or product.

SECTION J - CONTINUED

(2) As to defects in subparagraph a(3) of this Part I, whether or not also constituting a defect under subparagraphs (1), (2) or (4) of paragraph a of this Part I, within twenty-four (24) months after delivery of each aircraft or product.

c. The extent of Contractor's liability under this warranty as to defects in material or workmanship, defects arising from the selection of material or the process of manufacture, defects caused by faulty installation as aforesaid and such defects arising from such failure to conform to the Detail Specification as aforesaid, is limited to the repair of such defects in the aircraft, aircraft structure or system or, at the Contractor's election where applicable, to the repair or replacement (with a similar item free from the defect in question) of any system accessory, equipment or part which is defective in any of such respects.

d. The extent of Contractor's liability under this warranty as to defects inherent in the design as aforesaid is limited to the correction at its expense of all such defects in the aircraft, aircraft structure, system, accessory, equipment or part which is defective in design. In the event such design defects become apparent and the Government gives Contractor due and timely notice thereof within the applicable period set forth in subparagraph f(5) of this Part I and Contractor is obligated hereunder to correct such defect, Contractor shall also make such correction in any aircraft purchased hereunder which shall not have been delivered to the Government, provided that Contractor shall not be responsible nor deemed to be in default on account of any delays in performance of this contract due to any such corrections and, provided further, rather than accept a delay in delivery of such aircraft, the Government may elect to accept delivery and thereafter file a claim for a warranty correction hereunder as though the defect had become apparent immediately after delivery of such aircraft, and further, provided that nothing in this paragraph shall affect the Government's right to claim the same design defect with respect to any other delivered aircraft.

e. Contractor, or the Government with the approval of Contractor, shall make the foregoing repairs, replacements and corrections with reasonable care and dispatch in order that the aircraft, system, accessory, equipment or part involved may not be kept out of service longer than necessary. Contractor shall, within fifteen (15) calendar days following receipt of the Government's notification of a defect — (as required in subparagraph f(5) of this Part I) accompanied by the Government's request that it be permitted in such instance to make repair, replacement or correction, notify the Government of approval or disapproval of such request. Failing such timely notice by Contractor, approval of such request shall be deemed to have been given by

SECTION J - CONTINUED

Contractor. Should the Government be permitted to make any of the foregoing repairs, replacements and corrections, Contractor will establish a "standard" for the labor hours to repair such defect and will reimburse the Government for such "standard" hours or for the Government's or logistics support Contractor's actual labor hours to repair such defect, whichever is less, at the Government's or logistics support Contractor's direct labor rate plus a burden of fifty percent (50%) of said direct labor rate; provided, however, that in no event shall such amount exceed the applicable manufacturing direct labor rate of the Douglas Aircraft Company, plus a burden rate of one hundred percent (100%) of said manufacturing rate. Disassembly of the aircraft to correct the defects, removal of the defective or faulty structure, system, accessory, equipment or part and installation of the corrected or new structure, system, accessory, equipment or new part and reassembly of the aircraft shall be at Contractor's expense (except as to inspection, checkout and test effort) to the extent of and in accordance with the formula set forth above unless such work is performed by Contractor at its expense at its factory at Long Beach, California, or by Contractor at its expense at such other place as may be mutually agreed upon by Contractor and the Government, (When temporary or interim repairs, replacements and corrections are accomplished by the Government and not proposed or requested by Contractor, Contractor's liability to the Government hereunder shall not exceed the furnishing of a permanent repair, replacement or correction or the monetary equivalent thereof.) All transportation, costs of sending and returning aircraft and sending defective accessories, equipment or parts to the Contractor's factory shall be borne by the Government. The transportation costs for return to the Government of the repaired, replaced, or corrected accessories, equipment or part shall be borne by the Contractor. No approval by Contractor under this paragraph e shall constitute a determination that a defect, in fact, exists.

f. Contractor shall, as to each defect, be relieved of all obligation and liability under this warranty if:

(1) The aircraft is operated with any accessory, equipment or part not specifically approved by Contractor unless the Government furnishes reasonable evidence that such accessory, equipment or part was not a cause of the defect;

(2) The aircraft shall not have been operated or maintained in accordance with Contractor's operating and maintenance instructions furnished under this Contract's Data Requirements List (CDRL) unless the Government furnishes reasonable evidence that such operation or maintenance, as the case may be, was not a cause of the defect;

SECTION J - CONTINUED

(3) The aircraft shall not have been operated under normal ATCA mission use unless the Government furnishes reasonable evidence that such operation was not a cause of the defect;

(4) The aircraft shall have been repaired, altered or modified without Contractor's approval or if the aircraft shall have been operated subsequent to involvement in an accident unless the Government furnishes reasonable evidence that the accident or such repair, alteration, modification or operation after the accident was not a cause of the defect; provided, however, that this limitation, insofar as it relates to repairs and accidents, shall not be applicable to routine repairs or replacements, if such repairs or replacements are made with suitable material and according to standard practice and engineering or to operation after minor accidents;

(5) The Government does not (i) report the defect in writing or by telegram to Contractor's Warranty Administrator at its factory in Long Beach, California, within sixty (60) calendar days following such defect becoming apparent to the Government as provided in paragraph b of this Part I, and (ii) return the defective or faulty aircraft, accessory, equipment or part to said factory (or, if return to Contractor's factory is not feasible and Contractor so agrees in advance in writing, to the Government's base repair shop or other appropriate facility in the United States) within sixty (60) calendar days following the end of the applicable period of time specified in paragraph b of this Part I, or within sixty (60) calendar days following such defect becoming apparent, whichever is earlier, and further provided that, if for reasons beyond the Government's control, return of the item to Contractor's factory is not possible within said sixty (60) calendar day period and if the Government so notifies Contractor in writing, the said sixty (60) calendar day period will be waived but the Government must return the item to Contractor's said factory if, as and when such return does become feasible;

(6) The Government does not submit reasonable proof to Contractor within sixty (60) calendar days after the defect becomes apparent (except when such period is waived) that the defect is due to a matter embraced within the Contractor's warranty hereunder. Contractor shall approve or disapprove the Government's substantiation of its warranty claim in writing within sixty (60) calendar days of receipt thereof, and in the event of disapproval, the Contractor shall state its reasons therefor.

SECTION J - CONTINUED

With respect to matters made the subject of Contractor's approval under subparagraphs (1) and (4) of this paragraph f, Contractor's approval or disapproval thereof shall be made in writing to the Government within sixty (60) calendar days after the Government's timely written notice to Contractor's Warranty Administrator is received by Contractor at its Long Beach plant requesting approval and referring to this paragraph f. In the event of disapproval, Contractor shall set forth the reasons therefor in its statement of disapproval. Contractor's failure to deliver to the Government a written statement of approval or disapproval within such sixty (60) calendar day period shall (without extending or increasing Contractor's obligations hereunder in any way) constitute approval by Contractor of the subject matter of the particular request involved.

g. Normal wear and tear and the need for regular overhaul shall not constitute a defect or failure under this warranty.

h. When an aircraft, accessory, or item of equipment, or other deliverable item under this contract, has been corrected, repaired or replaced pursuant to the conditions of this provision, the period of the Contractor's warranty under this Part I with respect to such correction, repair, or replacement, whichever may be the case, shall be the same as those set forth for the original delivered item.

i. None of the warranties made by Contractor with respect to any aircraft, product or article delivered under this contract shall survive acceptance by the Government, except to the extent and upon the conditions specifically set forth in paragraph a through h of this Part I, inclusive, and the Part IV of this clause entitled "General."

Part II - Service Life Policy

In addition to the warranties set forth in the Part I of this clause entitled "Warranty," Contractor agrees that should DC-10 fleet-wide or repetitive failure occur in any of the covered components, then the provisions of this Part II shall apply.

a. Definitions

For the purposes of this Part II, the following definitions apply:

(a) Failure means any breakage of, or defect in, a covered component (except for corrosion as a result of improper maintenance procedures and practices) which has occurred and which can reasonably be expected to occur on a repetitive or DC-10 fleetwide basis.

SECTION J - CONTINUED

(b) Airframe component means any of the primary structural elements of the wing, fuselage and vertical and horizontal empennage of the aircraft as specified in Exhibit "A" attached hereto.

(c) Landing gear component means any of those primary static structural elements which are part of the landing gear installed in an aircraft at the time of delivery thereof to the Government, specified in Exhibit "B" attached hereto.

(d) Covered component means any airframe component or landing gear component.

(e) Landing means any normal touchdown wherein tires contact the ground including all touch and go's.

b. Service Life Policy

Should a failure occur in any covered component of an aircraft within the following periods (whichever is applicable):

(a) As to any airframe component of an aircraft, within thirty thousand (30,000) flying hours or within ten (10) years after delivery of such aircraft to the Government, whichever shall first expire.

(b) As to any landing gear component of an aircraft, prior to the accumulation by such component of an aggregate of twenty thousand (20,000) aircraft landings or thirty thousand (30,000) flying hours involving the use of such component or within ten (10) years after delivery of such component to the Government, whichever shall first occur.

Contractor will, at the price hereinafter provided and as promptly as practicable, either (i) design and furnish to the Government a correction for such failed covered component and provide any parts required for such correction (exclusive of standard parts) or (ii) furnish to the Government a replacement covered component for such failed component for installation of such correction or component by the Government in such aircraft or the affected landing gear.

c. Price

Any part or covered component which Contractor is required to furnish to the Government under this Policy in connection with correction or replacement of a covered component shall be furnished to the Government at a price determined in accordance with the following formula:

SECTION J - CONTINUED

$$P = \frac{CT}{N}$$

P = Price to the Government

C = The Contractor's then current spare parts sales price

As to airframe components:

T = The total flying time in hours during which the airframe component, which is the subject of a failure, has been used, and

N = Thirty thousand (30,000),

As to landing gear components, either:

T = The total number of airplane landings which have been accumulated by the landing gear component, which is the subject of a failure, and

N = Twenty thousand (20,000),

or

T = The total flying time in hours during which the landing gear component, which is the subject of a failure, has been used, and

N = Thirty thousand (30,000),

whichever yields the higher fraction.

d. General Conditions and Limitations

(1) The return to Contractor, if such return is practicable, of any covered component which is the subject of a failure necessary for redesigning studies, shall be at the Government's expense. Any required disassembly and reassembly of the aircraft or landing gear, or parts of either thereof, removal of the covered component which is the subject of a failure and reassembly and installation of the corrected or replacement covered component, shall be at the Government's expense, and if such disassembly, reassembly and installation is accomplished by Contractor at the Government's request, the prices to be charged for any such services shall not exceed the prices charged to other commercial customers of Contractor during substantially the same time period.

SECTION J - CONTINUED

(2) Contractor's obligations under this Policy are conditioned upon (i) the submission of reasonable proof to Contractor that the failure is embraced within the scope of this Policy; (ii) with respect to landing gear components, the maintenance by the Government of log books and other historical records available for inspection by Contractor and adequate to enable determination of whether the defect or failure claimed is covered by this Service Life Policy and, if so, the amount of the payment to be made to Contractor hereunder and adequate to enable determination that the servicing, overhaul, maintenance and modification of any such landing gear component or related equipment has been accomplished in accordance with subparagraphs (4) and (5) of this paragraph d and (iii) the Government must have reported the failure, breakage or defect of a covered component in writing or by telegram to Contractor's Warranty Administrator at its factory in Long Beach, California, within sixty (60) calendar days after any failure, breakage or defect in a covered component becomes evident.

(3) The provisions of paragraph f (except for subparagraphs (5) and (6) thereof) of the Part I of the clause entitled "Warranty," are incorporated herein by this reference and shall condition Contractor's obligations under this Policy with respect to any covered component.

~~(4) Contractor's obligations under this Policy shall not apply to any covered component which has not been correctly modified in accordance with Contractor's mandatory or recommended Service Bulletin specifications or instructions furnished by the Contractor to the Government provided, however, that:~~

(a) failure to correctly modify is the proximate cause of the failure; and

(b) the Government received the Service Bulletin in sufficient time to incorporate the modification.

(5) Contractor's obligations under this Policy shall not apply to any landing gear component with respect to which there has been the failure to either (i) correctly service, maintain and overhaul such landing gear component or the landing gear or the aircraft it is at any time a part of, in accordance with the applicable Contractor's instructions regarding such servicing, maintenance and overhaul, including, without limitation, the Contractor maintenance manuals, overhaul manuals and special instructions applicable to landing gears and their component parts or (ii) periodically service and maintain such landing gear component, landing gear and aircraft on a scheduled basis in accordance with recognized standards for scheduled air passenger carriers, subject to regulations by the Federal Aviation Administration.

e. Nature of Agreement

This Service Life Policy is neither a warranty, performance guarantee nor an agreement to modify the aircraft, airframe components or landing gear components to conform to new developments hereafter occurring in the state of airframe or landing gear design and manufacturing art. Contractor's obligation herein is to make only those corrections to the airframe components and landing gear components or furnish replacement therefor as provided in this Policy.

f. Assignment of Rights

The Government's rights under this Part II, except as set forth elsewhere in this provision, shall not be assigned, sold, leased, transferred or otherwise alienated by operation of law or otherwise, without prior Contractor consent thereto given in writing. Any unauthorized assignment, sale, lease, transfer or other alienation of the Government's rights under this Policy shall immediately void this Policy in its entirety.

Part III - Vendor Warranties and Indemnity Against Patent Infringement

a. The contractor shall make reasonable efforts to obtain through formal agreements with the manufacturers of accessories and items of equipment installed on the aircraft to the extent not covered by the Contractor's warranty and the Contractor's indemnity against infringement of patents and other proprietary rights, respectively, favorable warranties, indemnities against infringement of patents and other proprietary rights. The Contractor shall promptly advise the Government and Logistics Support Contractor as to the character and extent of protection afforded the Government by such agreements of indemnity and warranties so obtained and provide them, with all acquired rights, to the Government and Logistics Support Contractor. The Contractor shall contractually require that all vendor warranties conveyed to the Government can be administered by the Logistics Support Contractor.

b. The Contractor shall assist the Government in the resolution of any problems associated with all vendor warranties provided. In the event of a default by any such manufacturer in the performance of any material obligation under any applicable warranty obtained by the contractor from such manufacturer pursuant to this Provision, or in the event of a disclaimer of responsibility by such manufacturer for any defect constituting a breach of any such warranty and upon notice thereof to the Contractor, the warranties and all other terms and conditions of the Provision hereof entitled "WARRANTY AND SERVICE LIFE POLICY" shall become applicable to any accessories or items of equipment involved as if the same had been manufactured by the contractor or to its detailed design, except that the warranty periods as to such accessories or items of equipment shall be the lesser of (1) the warranty

SECTION J - CONTINUED

period as set forth in the applicable warranty of such manufacturer or (ii) the applicable warranty period set forth in the Provision hereof entitled "Warranty and Service Life Policy" and the Government agrees to assign to the contractor, and the contractor shall be subrogated to, all of the Government's rights against such manufacturer with respect to and arising by reason of such default or disclaimer, provided that this paragraph c shall not be applicable to engines or their manufacturer.

Part IV - General

a. THE WARRANTY AND SERVICE LIFE POLICY PROVIDED IN THIS CONTRACT, AND THE OBLIGATIONS AND LIABILITIES OF THE CONTRACTOR UNDER SAID WARRANTY AND SERVICE LIFE POLICY, ARE EXCLUSIVE AND IN LIEU OF, AND THE GOVERNMENT WAIVES, ALL OTHER REMEDIES, WARRANTIES, GUARANTEES OR LIABILITIES EXPRESS OR IMPLIED, WITH RESPECT TO EACH AIRCRAFT, PRODUCT AND ARTICLE DELIVERED HEREUNDER, ARISING BY LAW OR OTHERWISE (INCLUDING, WITHOUT LIMITATION, ANY OBLIGATION OR LIABILITY OF THE CONTRACTOR ARISING FROM NEGLIGENCE OR WITH RESPECT TO FITNESS, MERCHANTABILITY, LOSS OF USE, REVENUE OR PROFIT OR CONSEQUENTIAL DAMAGES). THIS WARRANTY OR SERVICE LIFE POLICY SHALL NOT BE EXTENDED, ALTERED OR VARIED, EXCEPT BY A WRITTEN INSTRUMENT SIGNED BY THE CONTRACTOR AND THE GOVERNMENT. THIS PROVISION SHALL NOT LIMIT THE GOVERNMENT'S RIGHTS OR THE CONTRACTOR'S OBLIGATIONS AS SPECIFIED IN THE CLAUSE ENTITLED "INSPECTION" EXCEPT THAT, WITH REGARD TO AIRCRAFT, THE GOVERNMENT'S RIGHTS BECAUSE OF LATENT DEFECTS ARE LIMITED IN THAT THE CONTRACTOR MUST BE NOTIFIED OF ANY LATENT DEFECT IN SUCH AIRCRAFT WITHIN THE TIME PERIOD SPECIFIED IN PART I PARAGRAPHS b(1) OR (2) AS THE CASE MAY BE.

b. All warranties specified in Part I above shall also apply to Support Equipment and Configuration alternate kits delivered pursuant to this contract.

c. The Government may, without contractor approval, designate the ATCA Logistics Support Contractor to act in its behalf in all instances where "the Government" is referenced above. The Government shall advise the contractor in writing of any such designation.

d. In all instances above where notification must be given to the contractor after a defect or other condition becoming apparent, evident, etc., this shall mean becoming apparent, evident, etc., to the Contracting Officer (CO), or the Logistics Support Contractor, where such delegation has been made.

SECTION J - CONTINUED

EXHIBIT "A"

TO PROVISION J-38 WARRANTY AND SERVICE LIFE POLICY

The following specific airframe items are subject to the provisions of Part II of the clause entitled "WARRANTY AND SERVICE LIFE POLICY:"

PYLONS - WING AND CENTER ENGINE

Pylon engine mount fittings
Pylon engine mount bulkheads
Spars
Side skin and skin stiffeners
Pylon wing attach angle and center engine support angles
Pylon wing attach bulkhead and center engine attach bulkhead

WINGS

Front and rear spars
Upper and lower stringers and plating between spars
Landing gear bulkhead and fitting
Dihedral and sweepback bulkhead
~~Flat support ribs in the wing~~
Wing to fuselage attach tee

FUSELAGE

Frames, plating, stringers and pressure bulkheads but excluding all doors

Fuel tank pressure bulkheads and panels
ARO station sighting - tunnel pressure panels
ARB support fitting
UARRSI pressure panel

EMPENNAGE

Vertical spars and plating between spars
Aft fuselage vertical stabilizer carry-through structure
Horizontal stabilizer spars, integral plating between spars

SECTION J - CONTINUED

EXHIBIT "B"

TO PROVISION J-38 WARRANTY AND SERVICE LIFE POLICY

The following specific landing gear components are subject to the provisions of Part II of the clause entitled "WARRANTY AND SERVICE LIFE POLICY."

MAIN GEAR AND CENTER LINE GEAR

Bogie beam and axles
Shock strut outer cylinder
Shock strut piston
Orifice support tube

NOSE GEAR

Strut piston and axle
Strut outer cylinder
Orifice support tube

APPENDIX E

MCDONNELL DOUGLAS PROPOSED C-17.WARRANTY

SECTION E

65. WARRANTY AND SERVICE LIFE POLICY

Part I -- Warranty

a. SCOPE OF WARRANTY

Subject to the limitations and conditions hereinafter set forth, Contractor grants to the Government the following warranties:

(1) Fleet Reliability, Maintainability and Availability (RM&A)

Contractor warrants that the fleet of C-X aircraft shall meet or exceed the RM&A values specified in this contract in effect at any given time in accordance with the RM&A requirements tables and growth curves contained in the System Specification.

(2) Contractual Specification Conformation, Design Integration, Material and Workmanship

Contractor warrants that each aircraft; its structures and systems; all spares, replacements, or repair parts; (but not including engines); and all items of support equipment, together with related data and software, shall upon delivery, with the exception of those portions which are stated to be design goals or objectives, be free from:

(i) Defects resulting from failure of the C-X system to conform to or perform in accordance with the specifications incorporated in this contract;

(ii) Defects in the design and integration thereof, including defects arising from selection of material or process of manufacture, in view of the state of the art as of the date of such design;

(iii) Defects in material resulting from defects in (A) the composition or substance of the material, (B) its manufacturing workmanship, except with respect to items not manufactured by Contractor or to Contractor's design or performance specifications;

SECTION 8

(iv) Defects in workmanship except that the workmanship of GFE items and items not manufactured by Contractor or to Contractor's design or performance specifications, shall not be warranted; and

(v) Defects caused by the installation of any article.

In addition to the warranty otherwise provided by this paragraph a.(2), it is expressly agreed that with regard to any defects discovered in any structural components of the durability test article by virtue of the durability test program, as defined by Annex 11, to the PSED Statement of Work, paragraphs 3.3.2, through the first forty-five thousand (45,000) hours of durability test, the warranty of this paragraph a.(2) shall extend to such defects, discovered in the durability test article, to the same extent as if such defects has been discovered in a production aircraft during the warranty periods set forth in paragraph d. hereof, notwithstanding that such warranty periods may have expired for any of the aircraft delivered hereunder.

(3) Installation of Parts

Contractor warrants that all systems, accessories, equipment, subassemblies, parts, or other articles, including engines, shall be installed in such manner as to insure conformance to and performance in accordance with the specifications of this contract and further warrants that in no event will its installation of any such accessories, equipment, subassemblies, parts, or other articles, including engines, be such as to invalidate any warranty of any manufacturer thereof.

(4) Design Information

Contractor warrants that detail design information, technical orders, technical data, and engineering data (but not including engine data) furnished pursuant to this contract and all other detail design information or technical or engineering data supplied by Contractor and furnished to the Government for

SECTION H

the purpose of repair, rework, replacement logistics support, maintenance, maintenance operations, or maintenance training shall be free from defect, notwithstanding that any such detail design information, technical orders, or technical or engineering data shall have been verified by the Government. Data not supplied for the purpose of repair, rework, replacement, logistics support, maintenance, maintenance operations, or maintenance training shall be warranted in accordance with the General Provision of this contract entitled, "Warranty of Technical Data."

b. REMEDIES

(1) Corrections of Defects

(i) Contractor Corrections

(A) The Government's remedy for a breach of the warranties set forth herein and Contractor's obligation and liability therefor, shall be Contractor's performance of the following at no change in contract targets or ceiling prices:

(a) As regards paragraphs a.(1) and (2) hereof--the correction, repair, rework, replacement, or redesign of any nonconforming or defective structure, system, component, or item of support equipment, including spares delivered under the separate spares contract, F33657-81-C-2109, determined to be the cause or contributing cause of the aircraft's defective condition or failure to conform to and perform in accordance with the specifications (including RM&A values), such that said defect or nonconformance is eliminated;

(b) As regards paragraph a.(3) hereof--the correction of any such improper installation and to the extent such installation shall have caused the invalidation of any vendor warranty required to be passed through to the Government pursuant to paragraph b.(2) hereof or any engine warranty pursuant to b.(3) hereof, Contractor shall, with regard to any such invalidated warranty, assume the liability the vendor or engine manufacturer would have had if such warranty had not been invalidated.

SECTION B

(c) As regards any defect in design information, technical orders, or technical or engineering data pursuant to paragraph a.(4) hereof--correction of such design information, technical order, or technical or engineering data and repair, rework, or replacement of any damage to the immediate subsystem or piece of support equipment caused by the Government's reasonable reliance upon such defective information, technical order, or technical or engineering data. For the purpose of this warranty, the "subsystems" of the air vehicle are those major subdivisions listed in Table "C", attached hereto; the term "immediate subsystem" refers to the damaged subsystem upon which repair or maintenance was being accomplished in reliance upon the defective data and not to other subsystems damaged consequentially. Under no circumstance shall the entire airframe or any substantial portion thereof be deemed to be an "immediate subsystem."

(d) With respect to any defect or specification nonconformance or failure to meet RM&A values as embraced by this warranty, including any defect in the aircraft's structural components discovered by virtue of the durability test program through the first forty-five thousand (45,000) hours of durability test, Contractor shall correct such defects by appropriate modification of the design and/or manufacturing processes or procedures for all undelivered aircraft, whether in the process of manufacture or to be manufactured, and shall retrofit all completed aircraft, whether delivered or undelivered to correct said defects, nonconformances or failures. Provided, however, that regarding defects embraced by paragraph a.(1) hereof and any defect discovered in the durability test article by virtue of the first forty-five thousand (45,000) hours of durability test, Contractor's obligation to retrofit aircraft previously delivered under this contract at no change in contract targets or ceiling prices, shall be limited to the number of aircraft procured through the first two production options of this contract, but not to exceed 16 aircraft.

(B) Any repair, rework, replacement, or correction of any nonconforming or defective aircraft structure, system,]

SECTION E

Component, or item of equipment performed by Contractor pursuant to this warranty shall be promptly completed. In the event that repair, rework, replacement, or correction of a nonconforming or defective structure, system, accessory, item of equipment, or part is infeasible by reason of the loss, damage, or destruction of the aircraft as a result of the specification nonconformance or defect, Contractor's liability shall be limited to the cost of repair, replacement, or correction of the defect as if it had been performed. With respect to defects within the scope of Paragraphs a.(1), (2), (3), and (4) above, Contractor shall not be liable for consequential damages to the aircraft or support equipment caused by or related to failure of an item or component determined to be defective hereunder, beyond the immediate subsystem of which such item or component is a part. Under no circumstance shall the entire airframe or any substantial portion thereof be deemed to be an "immediate subsystem."

(C) Contractor's liability under this warranty for correction of defects pursuant to paragraphs a.(1), (2), (3) and (4) shall also extend to correction of such defect as it relates to any aircraft purchased hereunder which shall not have been delivered to the Government, provided that Contractor shall not be responsible nor deemed to be in default on account of any delays in performance of this contract due to any such corrections and, provided further, rather than accept a delay in delivery of such aircraft, the Government may elect to accept delivery and thereafter file a claim for a warranty correction hereunder as though the defect had become apparent immediately after delivery of such aircraft, and further, provided that nothing herein shall affect the Government's right to claim the same design defect with respect to any other delivered or undelivered aircraft.

(D) Disassembly of the aircraft to effect removal of any defective or faulty structure, system, or component for shipment to Contractor's plant for correction, repair or replacement under this warranty and reinstallation of the corrected or new structure, system, or component and reassembly of the aircraft performed by the Government (except as to inspection,

SECTION 8

checkout and test effort) shall entitle the Government to reimbursement in accordance with the formula set forth in paragraph b.(1)(ii)(B) unless such work is performed by Contractor, at no change in contract targets or ceiling prices, at such place as may be mutually agreed upon by Contractor and the Government.

(E) If the Fleet RM&A performance observed at ORE fails to meet specification requirements and is thereby a defect under this warranty, the corrective action proposed by Contractor under paragraph b.(1)(v) hereof shall be verified after implementation to determine if the RM&A performance has in fact been corrected. Such verification shall be in accordance with Contractor's proposed corrective action plan submitted pursuant to paragraph b.(1)(v) hereof, but shall as a minimum require comparison of Actual Fleet RM&A performance against the values specified in the System Specification, Appendix Section 70, using the values from the growth curves applicable to the number of hours on the fleet at the time verification in fact occurs. If Contractor's corrective action does not remedy the defective RM&A performance, he shall propose and implement additional corrective actions until such defects are remedied. Verification of such additional corrective actions shall be as provided above.

(ii) Government Corrections

(A) As an alternative to the performance of the work by Contractor under paragraph b.(1)(i) hereof, such repairs and corrections (excluding correction of design defects--see paragraph a.(2) hereof) may, at the Government's option, be performed by the Government or any logistics support organization designated by the Government. Should the Government elect to effect such repairs or corrections, Contractor will, under the conditions set forth below, reimburse the Government for the repair, rework or correction of any specification nonconformance or defect under paragraphs a.(1), (2) (excluding defects in design), (3) and (4) at the Government's repair facilities or by a logistics support organization designated by the Government, and will recognize same for any and all other purposes as a correction under this warranty.

SECTION H

(B) Should the Government elect to make any of the foregoing repairs, replacements and corrections, Contractor will negotiate with the Government a "standard" for the labor hours to repair such defect and will reimburse the Government for such "standard" hours or for the Government's or logistics support organization's actual labor hours to repair such defect, whichever is less, at the Government's or logistics support organization's direct labor rate plus a burden of fifty percent (50%) of said direct labor rate; provided, however, that in no event shall such amount exceed the applicable manufacturing direct labor rate of the Douglas Aircraft Company plus a burden rate of one hundred percent (100%) of said manufacturing rate. Disassembly of the aircraft to correct the defects, removal of the defective or faulty structure, system, accessory, equipment or part and installation of the corrected or new part and reassembly of the aircraft if by the Government (except as to inspection, checkout and test effort) shall also entitle the Government to reimbursement for such effort in accordance with the formula set forth above unless such work is performed by Contractor at its factory at Long Beach, CA or by Contractor at such other place as may be mutually agreed upon by Contractor and the Government at no change in contract targets or ceiling prices. (When temporary or interim repairs, replacements and corrections are accomplished by the Government and not proposed or requested by Contractor, Contractor's liability to the Government hereunder shall not exceed the furnishing of a permanent repair, replacement or correction of the monetary equivalent thereof.)

(C) In the event of Government correction, Contractor shall reimburse the Government for the parts and materials used at the cost to the Government.

(iii) Transportation Charges

(A) When the Government returns supplies to the Contractor for correction or replacement pursuant to this clause, the Contractor shall be liable for transportation charges up to an amount equal to the cost of transportation by the usual commercial method of shipment from the designated destination point under this contract to the Contractor's plant, in addition to any charges provided for by (B) below. The Contractor shall also bear the responsibility for the supplies while in transit.

SECTION B

(B) When compliance with the terms of this clause by the Contractor involves shipment of corrected or replacement supplies from the Contractor to the Government, the Contractor shall be liable for transportation charges up to an amount equal to the cost of transportation by the usual commercial method of shipment from the Contractor's plant to the designated destination point under this contract, in addition to any charges provided for by (A) above. The Contractor shall also bear the responsibility for the supplies while in transit.

(C) For the purposes of this paragraph (iii), the word "supply" in the phrase "supplies while in transit" shall not include an aircraft.

(iv) Contractor, or the Government at its (the Government's) election, shall make the foregoing repairs, replacements, or corrections with reasonable care and dispatch in order that the aircraft, system, component, or item of equipment involved may not be kept out of service longer than necessary.

(v) Contractor shall, together with the written acceptance or denial of warranty liability required by c.(2) hereof, within forty-five (45) calendar days after receipt of the Government's notification of defect, submit to the Government in as much detail as possible: (A) a complete identification of the cause; (B) the proposed method for effecting and verifying the repair, replacement, or correction; (C) the Life Cycle Cost impact of (B) above; and (D) the proposed schedule for accomplishing (B) above. The above information shall be submitted without regard to whether Contractor accepts or denies liability pursuant to c.(2) hereof.

(vi) Should the Government during the course of any service, maintenance, T.O., T.C.T.O., or service bulletin compliance or any preflight or postflight operation or inspection whether scheduled or unscheduled effect the repair, removal, and/or replacement of any item determined during or after such repair, removal, or replacement to be defective and/or nonconforming with specification pursuant to this warranty, Contractor's liability therefore shall be the same as if said defect or specification nonconformance was discovered prior to said repair, replacement, or removal and the Government had elected pursuant to paragraph b.(1)(ii) hereof, to make the repair, rework, or correction of

SECTION H

such specification nonconformance or defect itself. In the case of removal and replacement as described in this paragraph b.(1)(vi), the Government shall hold any removed item for a period not to exceed sixty (60) days subject to inspection by Contractor and further action pursuant to the notice and remedy provisions of this warranty.

(2) Vendor Warranties

(i) Contractor shall make reasonable efforts to obtain for and on behalf of the Government through formal written agreements with its subcontractor manufacturers and vendors, warranties, certified by such subcontractors and vendors to be at least as favorable as those provided by such manufacturers/vendors to their most favored commercial customers, covering the accessories, components, and items of equipment installed on the aircraft which are not manufactured by Contractor or to Contractor's design or performance specifications. Such warranties shall not require covered items to be serviced and maintained by FAA certified mechanics.

(ii) Contractor shall promptly advise the Government as to the character and extent of protection afforded the Government by such warranties so obtained.

(iii) Contractor shall, during the term of Interim Contractor Support (ICS), administer and enforce for and on behalf of the Government, all manufacturer/vendor warranties obtained. The Government will consider the extent to which Contractor saves the Government expenses for labor and/or materials by enforcement of such warranties against manufacturers/vendors in the operation of the Award Fee Special Provision, H-44, hereof. The operation of the award fee provision is subjective and completely discretionary on the part of the Government; however, the Government will consider, in making the award fee determination hereunder, the degree to which Contractor has enforced manufacturer/vendor warranties to the Government's benefit.

SECTION 8

(iv) Contractor shall make reasonable efforts to obtain written agreement with respect to all manufacturer/vendor warranties that upon termination of any phase of ICS the remaining term of such warranties shall, at the election of the Government, be transferable to the Government for administration and enforcement by the Government or any designated Logistics Support Organization.

(3) Engine Warranty

Contractor shall obtain for and on behalf of the Government, through formal written agreement with the engine manufacturer, a warranty and service policy on installed, uninstalled, and spare engines, spare engine parts, and engine technical and engineering data which warranty and service policy shall be certified by the engine manufacturer to be at least as favorable to the Government in terms of scope, breadth and duration of protection and remedies as that provided by said engine manufacturer to its most favored commercial customers during substantially the same time period for the same family of engines taking into account severity of use. This warranty shall not require the engines to be serviced and maintained by FAA certified mechanics. Contractor shall promptly advise the Government or any designated logistics support organization as to the character and extent of protection afforded the Government by such warranty so obtained and provide such, with all acquired rights, to the Government or any logistics support organization designated by the Government. Contractor shall contractually require that such engine warranty and service policy may be conveyed to the Government and further that such warranty and service policy can be administered by any logistics support organization designated by the Government. Contractor shall assist the Government in the resolution of any problems associated with the engine warranty and service policy provided.

c. LIMITATIONS

(1) Contractor shall, as to each defect, be relieved of liability under this warranty if:

SECTION H

(i) The aircraft is operated with any accessory, equipment or part not specifically approved by Contractor unless the Government furnishes reasonable evidence that such accessory, equipment or part was not a cause of the defect;

(ii) The aircraft shall not have been operated or maintained in accordance with Contractor's operating and maintenance instructions furnished under this Contract's Data Requirements List (CDRL) unless the Government furnishes reasonable evidence that such operation or maintenance, as the case may be, was not a cause of the defect;

(iii) The aircraft shall have been engaged in flight operations in a theater of actual combat, provided that it is demonstrated that such operations were the cause of the defect;

(iv) The aircraft shall have been altered or modified without Contractor's approval or if the aircraft shall have been operated subsequent to involvement in an accident unless the Government furnishes reasonable evidence that such alteration, modification or operation after the accident was not a cause of the defect; provided, however, that this limitation, shall not be applicable to routine repairs or replacements made with suitable material and according to standard practice and engineering or to operation after minor accidents;

(v) The Government does not submit reasonable evidence to Contractor that the defect is due to a matter embraced within the Contractor's warranty hereunder and that said defect was discovered within the warranty period.

(2) The Contractor shall accept or deny the Government's substantiation of its warranty claim, together with submission of the information required by b.(1)(v) hereof, in writing to the Government within forty-five (45) calendar days after the Government's timely written notice to Contractor's Warranty Administrator is received by Contractor at its Long Beach, California plant. In the event of denial, Contractor shall state its reasons therefor. Contractor's failure to

SECTION 5

deliver to the Government a written statement of acceptance or denial within such forty-five (45) calendar day period shall constitute acceptance by Contractor of its obligation to perform in accordance with the paragraph hereof entitled, "Remedies," at no change in contract targets or ceiling prices.

(3) If Contractor, by issuance of written denial does not agree that he is responsible pursuant to this warranty to correct, repair or replace the defect alleged by the Government, he shall nevertheless proceed in accordance with the written request of the PCO, if any, citing this paragraph, to effect such correction, repair or replacement. Any such failure of the Government and Contractor to agree concerning whether any alleged defect is embraced by this warranty shall be treated as a dispute concerning a question of fact pursuant to the clause of this contract entitled "Disputes." In the event the Contractor, pursuant to direction under this paragraph, effects correction, repair, or replacement of an alleged defect which is later determined not to be embraced by this warranty, the contractor shall be entitled to an equitable adjustment therefor.

d. WARRANTY PERIODS

(1) Defects as covered by paragraph a.(1) of this warranty must be discovered by the Government prior to the expiration of 90 days after the completion of the Operational Readiness Evaluation as defined in paragraph 4.1.1.2 of the System Specification, but in no event later than 180 days after Initial Operational Capability (IOC). For the purposes of this Warranty, IOC shall be defined as the delivery of 12 production-configured aircraft, with all ancillary items required by this contract to perform the assigned mission, including, but not limited to: spares, support equipment, and data.

(2) Defects covered by paragraphs a.(2) and (3) must be discovered by the Government prior to the expiration of 180 days from the delivery of the last aircraft procured through the first two production options under this contract, provided, however, that any such defect discovered in the durability test article during 45,000 hours of durability test shall be deemed a defect found in each warranted aircraft as if it had been discovered during this same period.

SECTION H

(3) Defects covered by paragraph a.(4) of this Warranty must be discovered by the Government prior to the expiration of 180 days from the delivery of such design information.

e. GENERAL

(1) "Defect" shall be defined as any failure, fault, weakness or like characteristic or condition which causes the C-X aircraft to fail to conform to and perform in accordance with the specifications and requirements of this contract, including but not limited to: performance specifications, parameters, and requirements; specified levels of reliability, maintainability, and availability for the fleet of C-X aircraft; specified tolerances and/or margins of safety; and other specified operational capabilities, limitations, and requirements, but only to the extent that such failure, fault, weakness, characteristic, or condition results from Contractor's failure to comply, by act or omission, with the C-X SOW, System Specification for C-X, Air Vehicle Prime Item Specification, Support Equipment General Specification, other requirements of the schedule of this contract or good practice within the aircraft industry, taking into account the state of the art at the time of design and manufacture. Provided, however, normal wear and tear and the need for regular overhaul or periodic maintenance shall not constitute a defect or failure under this warranty. Further provided, that with regard to those structural elements of the airframe and landing gear which are listed in Tables "A" and "B" hereof, cracks shall not constitute a defect or failure hereunder unless any such crack or cracks when found or if left unrepaired would grow within the aircraft's structural lifetime, as defined in the System Specification, to a length that, would: (i) reduce the structural strength to the extent that the structure might not sustain limit load; or (ii) cause functional impairment. Further provided that with regard to those structural elements of the airframe and landing gear which are not listed in Tables "A" and "B" hereof, cracks shall not constitute a defect or failure hereunder unless such crack or cracks, when found or if left unrepaired for the period between scheduled maintenance would cause a functional failure of the air vehicle's system.

SECTION 2

(2) The Government shall (A) report the defect in writing or by telegram to Contractor's Warranty Administrator at its factory in Long Beach, California within thirty (30) calendar days following such defect having been discovered by the Government, provided such defect was discovered within the effective period of the warranty hereunder, and (B) return the defective or faulty aircraft, accessory, equipment, or part to said factory (unless return to Contractor's factory is not feasible or the Government elects to effect the repair at its own or a logistics support organization facility) within sixty (60) calendar days following the end of the applicable period of time specified in paragraph d. of this Part I, or within sixty (60) calendar days following such defect having been discovered by the Government, whichever is earlier, and further provided that if for reasons beyond the Government's control, return of the item to Contractor's factory is not possible within said sixty (60) calendar day period and if the Government so notifies Contractor in writing, the said sixty (60) calendar day period shall be waived, but the Government must return the item to Contractor's said factory if, as and when, such return does become feasible. Where return is feasible and the Government elects not to effect the repair but to have Contractor make the repair, Contractor may elect to have the Government retain the defective item for a period not to exceed sixty (60) days for Contractor directed disposition or dispose of the defective item, if it is to be replaced.

(3) A defect shall be deemed to have been discovered by the Government at the time it in fact becomes known to the Principal Contracting Officer (PCO) without regard to whether it should have or could have become known at any earlier time and without regard to whether any other officer, employee or agent of the Government had prior knowledge of same, provided, however, that a defect shall be deemed to have been discovered by the Government not later than six (6) months following its discovery and documentation in accordance with T.O. 00-35D-54 by an officer or employee of the Government other than the PCO.

SECTION 2

(4) The design, material, workmanship, and specification conformation (to its own specifications) of Government Furnished Equipment (GFE) are not embraced by this warranty, except to the extent of defects in specification conformation (paragraph a.(2)(i)) and system design and integration (paragraph a.(2)(ii)) as they relate to system integration, for which Contractor has total responsibility, and defects caused by or related to the installation of any system, accessory, item of equipment, subassembly, part, or other article (paragraph a.(3)).

(5) The Government may, without Contractor approval, designate a logistics support organization to act in its behalf in all instances where "the Government" is referenced above. The Government shall advise Contractor in writing of any such designation.

(6) As used in this warranty with respect to any aircraft, structure, system, accessory, item of equipment, part, or other product, the word "delivery" shall mean: the physical transfer of possession to the Government or the time of acceptance by the Government--i.e., execution of DD Form 250--whichever shall later occur.

(7) It is the intent of the parties that Contractor shall be responsible hereunder to effect whatever corrective action is necessary to remedy a defect as defined in e(1) hereof of the C-X aircraft system, including, if necessary, replacement, repair, rework or other correction of parts or components of the aircraft. It is not the intent of the Government for this warranty to apply to deficiencies or malfunctions in individual parts or components of the aircraft, unless such deficiencies or malfunctions cause or contribute to C-X aircraft system failure to conform to or perform in accordance with specifications of this contract. Individual deficiencies in components or items which do not cause or contribute to a system defect shall be warranted, if at all, by vendor warranties on such items.

(8) THE WARRANTIES PROVIDED HEREIN ARE EXCLUSIVE AND IN LIEU OF, ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, WITH RESPECT TO EACH AIRCRAFT, PRODUCT AND ARTICLE DELIVERED HEREUNDER INCLUDING ANY WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PURPOSE. PROVIDED, HOWEVER, THE RIGHTS AND REMEDIES OF THE GOVERNMENT

SECTION E

PROVIDED IN THIS CLAUSE: (i) SHALL NOT BE AFFECTED IN ANY WAY BY ANY OTHER PROVISIONS UNDER THIS CONTRACT CONCERNING THE CONCLUSIVENESS OF INSPECTION AND ACCEPTANCE; AND (ii) ARE IN ADDITION TO AND DO NOT LIMIT ANY RIGHTS AFFORDED TO THE GOVERNMENT BY ANY OTHER CLAUSE OF THIS CONTRACT. THIS WARRANTY SHALL NOT BE EXTENDED, ALTERED OR VARIED, EXCEPT IN WRITING BY A BILATERAL CONTRACT MODIFICATION.

Part II -- Service Life Policy

In addition to and NOT in substitution, for the warranties set forth in Part I of this clause entitled "Warranty", Contractor agrees that should a repetitive failure occur in any of the covered components, then the Government is granted the rights, hereinafter set forth in this Part II.

a. DEFINITIONS

For the purpose of this Part II, the following definitions apply:

(1) Repetitive failure means any breakage of, or defect in, a covered component (except for corrosion as a result of improper maintenance procedures and practices) which has occurred and which can reasonably be expected to occur again.

(2) Airframe component means any of the primary structural elements of the wing, fuselage, and vertical and horizontal empennage of the aircraft as specified in Table "A" attached hereto.

(3) Landing gear component means any of those primary structural elements which are part of the landing gear installed in an aircraft at the time of delivery thereof to the Government, specified in Table "B" attached hereto.

(4) Covered component means any airframe component or landing gear component, and any such spare or replacement component purchased from Contractor.

SECTION H

(5) Landing means any normal touchdown wherein tires contact the ground including all touch and go's.

(6) As used in this Service Life Policy, the term delivery shall have the same meaning as that set forth in paragraph e.(6) of Part I entitled, "Warranty".

b. OPERATION OF SERVICE LIFE POLICY

Should a repetitive failure occur in any covered component of an aircraft within the following periods (whichever is applicable):

(1) As to any airframe component of an aircraft, within ten thousand (10,000) flying hours or within ten (10) years after delivery of such aircraft to the Government, whichever shall first expire.

(2) As to any landing gear component of an aircraft, prior to the accumulation by such component of an aggregate of twenty thousand (20,000) aircraft landings or ten thousand (10,000) flying hours involving the use of such component or within ten (10) years after delivery of such component to the Government, whichever shall first occur.

Contractor shall, at the price hereinafter provided and as promptly as practicable, either (i) design and furnish to the Government a correction for such failed covered component and provide any parts required for such correction (exclusive of common hardware) or (ii) furnish to the Government a replacement covered component for such failed component for installation of such correction or component by the Government in such aircraft or the affected landing gear.

c. PRICE

Any part of a covered component which Contractor is required to furnish to the Government under this Policy in connection with correction or replacement of a covered component shall be furnished to the Government at a price determined in accordance with the following formula:

$$P = \frac{CT}{N}$$

SECTION B

P = Price to the Government

C = The Contractor's then current spare parts price

As to airframe components:

T = The total flying time in hours during which the airframe component, which is the subject of a failure, has been used, and

N = Ten Thousand (10,000)

As to landing gear components, either:

T = The total number of aircraft landings which have been accumulated by the landing gear component, which is subject to a failure, and

N = Twenty thousand (20,000) (Aircraft useful life in number of landings), or

T = The total flying time in hours during which the landing gear component, which is the subject of a failure, has been used, and

N = Ten Thousand (10,000),

whichever yields the higher fraction.

d. GENERAL CONDITIONS AND LIMITATIONS

(1) The return to contractor pursuant to this Part II, if such return is practicable, of any covered component which is the subject of a failure necessary for redesigning studies, shall be at the Government's expense. Any required disassembly and reassembly of the aircraft or landing gear, or parts of either thereof, removal of the covered component which is the subject of a failure and reassembly and installation of the corrected or

SECTION B

replacement covered component, shall be at the Government's expense, and if such disassembly, reassembly and installation is accomplished by Contractor at the Government's request, the prices to be charged for any such services shall not exceed the prices charged to its most favored commercial customers of Contractor during substantially the same time period.

(2) Contractor's obligations under this Policy are conditioned upon (i) the submission by the Government of reasonable evidence to the Contractor that the failure is embraced within the scope of this Policy; (ii) with respect to landing gear components, the maintenance by the Government of log books and other historical records available for inspection by Contractor and adequate to enable determination of whether the defect or failure claimed is covered by this Service Life Policy and, if so, the amount of the payment to be made to Contractor hereunder and adequate to enable determination that the servicing, overhaul, maintenance and modification of any such landing gear component or related equipment has been accomplished in accordance with subparagraphs (5) and (6) of this paragraph d; and (iii) the Government must have reported the failure, breakage or defect of a covered component in writing or by telegram to Contractor's Warranty Administrator at its factory in Long Beach, CA within calendar days after any failure, breakage or defect in a covered component has been discovered by the Government.

(3) The provisions of paragraph c.(1) (except for subparagraph (v) thereof) of the Part I of the clause entitled "Warranty", are incorporated herein by this reference and shall condition Contractor's obligation under this Service Life Policy with respect to any covered component.

(4) A failure, breakage or defect shall be deemed to have been discovered by the Government at the time it in fact becomes known to the Principal Contracting Officer (PCO) without regard to whether it should have or could have become known at any earlier time and without regard to whether any other officer, employee, or agent of the Government had prior knowledge of same.

SECTION B

(5) Contractor's obligation under this Policy shall not apply to any covered component which has not been correctly modified in accordance with T.C.T.O.s, provided however, that:

(a) Failure to correctly modify is the proximate cause of the failure; and

(b) The Government received the TCTO in sufficient time to incorporate the modification.

(6) Contractor's obligation under this Policy shall not apply to any landing gear component with respect to which there has been the failure to correctly service, maintain and overhaul such landing gear component or the landing gear or the aircraft it is at any time a part of, in accordance with the applicable Contractor's instructions regarding such servicing, maintenance and overhaul.

e. NATURE OF AGREEMENT

This Service Life Policy is neither a warranty, performance guarantee, nor an agreement to modify the aircraft, airframe components, or landing gear components to conform to new developments hereafter occurring in the state of airframe or landing gear design and manufacturing art. Contractor's obligation herein is to make only those corrections to the airframe components and landing gear components or furnish replacement therefor as provided in this Policy. Provided however, that to the extent that any defect or failure is embraced both by the warranty provided in Part I hereof and also by the Service Life Policy of this Part II, Contractor shall first be liable for that repair, rework, or replacement to which the Government is entitled by virtue of the warranty provided in Part I hereof.

SECTION E

f. ASSIGNMENT OF RIGHTS

The Government's rights under this Part II, except as set forth elsewhere in this provision, shall not be assigned, sold, leased, transferred or otherwise alienated by operation of law or otherwise, without prior Contractor consent thereto given in writing. Any unauthorized assignment, sale, lease, transfer or other alienation of the Government's rights under this Policy shall immediately void this Policy in its entirety.

g. COSTS IN EXCESS OF PRICE TO THE GOVERNMENT

Costs incurred by Contractor in complying with the Service Life Policy in excess of the Price to the Government, as calculated pursuant to paragraph c. hereof, shall be allocable to this contract, but shall not be allowable as a direct or indirect charge under any other Government contract.

PART III

(i) INCENTIVE PRICE REVISION (IF APPLICABLE)

All costs incurred or estimated to be incurred by the Contractor in complying with this clause shall be considered when negotiating the total final price under the Incentive Price Revision clause of this contract. After establishment of the total final price, Contractor compliance with this clause shall be at no increase in the total final price. Any equitable adjustments made pursuant to this clause shall be governed by the paragraph entitled "Equitable Adjustments Under Other Clauses" in the Incentive Price Revision clause of this contract.

SECTION B

TABLE "C"

TO PROVISION H.65 WARRANTY AND SERVICE LIFE POLICY

The Subsystems of the air vehicle, for the purposes of this Provision H.65, are as follows:

1. Structure (Primary and Secondary)
2. Flight Control
3. Life Support
4. Landing Gear
5. Avionics (including Flight Instruments & Aircraft Lighting)
6. Crew Provisions
7. Propulsion
8. Hydraulics
9. Environmental Control
10. Fire Protection
11. Fuel
12. Auxiliary Power and Engine Starting
13. Electrical Generation and Distribution
14. Cargo Handling and Restraint

SECTION H

TABLE "B"

TO PROVISION H.65 WARRANTY AND SERVICE LIFE POLICY

The following specific landing gear components are subject to the provisions of Part II of the clause entitled "WARRANTY AND SERVICE LIFE POLICY":

MAIN GEAR

Axles
Trailing Arm Beam
Shock strut outer cylinder
Shock strut piston
Structural Support Members (Drag Braces, etc.)
Post

NOSE GEAR

Axle
Strut piston
Strut outer cylinder
Orifice support tube
Structural Support Members (Drag Braces, etc.)

SECTION 8

66. APPLICATION OF CORRECTION OF DEFICIENCIES CLAUSE TO FOLLOW-ON CONTRACTUAL EFFORT AND APPLICATION OF SPECIAL PROVISION H.65 TO CHANGE PROPOSALS UNDER THIS CONTRACT

a. Contractor and the Government hereby agree to incorporate the provisions set forth in paragraph c. below, entitled "CORRECTION OF DEFICIENCIES," in the next annual buy of C-X production aircraft (FY86), with the agreement that system level RM&A requirements shall be excluded from its coverage. Contractor further agrees the cost of this incorporation shall not exceed 1% of proposed aircraft unit target price or firm fixed price (for the purposes of this Provision, H.66, target amounts, ceiling price, and firm fixed price are used together; the precise terminology will be specified as individual contractual actions are definitized.)

b. Additionally, for any change proposals submitted under this contract, Contractor hereby agrees to apply Special Provision H.65 of this contract to FS2D and all production options. Contractor further agrees that the cost of this application shall not exceed 2% of the target price or firm fixed price of the proposed change.

c. CORRECTION OF DEFICIENCIES

a. Definitions as used in this clause:

(1) "deficiency" means any conditions or characteristic in any supplies, but not including engines or other items not manufactured by Contractor or to Contractor's design or performance specifications (which term shall include related technical data) or services furnished hereunder, which is not in compliance with the requirements of this contract. "Deficiency" also means any condition or characteristic in any supplies furnished hereunder (including, but not limited to, spares, support equipment, training equipment and related technical data) which may be in compliance with the particular contract specifications for such individual supplies at the time furnished to the Government but which must be altered, redesigned, reconfigured or reworked because of other deficiencies to assure that the integrated C-X System will meet all of the requirements of this contract. (Failure of the fleet to meet system level RM&A requirements shall not be deemed a deficiency);

SECTION 8

(2) "correction" means any and all actions necessary to eliminate any and all deficiencies;

(3) "acceptance" of supplies and services means the execution of a DD Form 250 or similar document by the Government for the supplies or services, or portions thereof, furnished under this contract; provided however, that acceptance thereof, with identified deficiencies, shall not be deemed acceptance to the extent of such deficient supplies.

b. General

(1) The rights and remedies of the Government provided in this clause:

(i) shall not be affected in any way by any other provisions under this contract concerning the conclusiveness of inspection and acceptance; and

(ii) are in addition to and do not limit any rights afforded to the Government by any other clause of this contract.

(2) This clause shall apply as follows:

(i) To deficiencies in specification conformation, design, integration, installation, workmanship, and material deficiencies discovered by either the Government or the Contractor within one hundred and eighty (180) days after acceptance of the respective supplies by the Government.

(ii) To deficiencies in technical data, regardless of the nature of the deficiency disclosed by either the Government or the Contractor within six months after acceptance of the delivered data (as specified in block 7, 8, and 9 of the CDRL).

SECTION II

(3) The Contractor shall not be responsible under this clause for the correction of deficiencies in Government furnished property, except for deficiencies in installation, unless the Contractor performs or is obligated to perform any modifications or other work on such property. In that event, the Contractor shall be responsible for correction of deficiencies to the extent of such modifications or other work.

c. Modification of Contract With Respect to Uncorrected Deficiencies.

In the event of timely notice of a decision not to correct or only to partially correct, the Contractor shall promptly submit a technical and cost proposal to amend the contract to permit acceptance of the affected supplies or services in accordance with the revised requirements, and an equitable reduction in contract target amounts, ceiling price or firm fixed price shall promptly be negotiated by the parties and reflected in a supplemental agreement to this contract.

d. Deficiencies in Supplies or Services Not Yet Accepted.

If the Contractor becomes aware at any time before acceptance by the Government (whether before or after tender to the Government) that a deficiency exists in any supplies or services, he shall promptly correct the deficiency or, if he elects to invoke the procedures in c. above, he shall promptly communicate information concerning the deficiency to the Contracting Officer in writing, together with his detailed recommendation for corrective action.

e. No Extension in Time for Performance; No Increase in Contract Price

(1) The Government shall not be responsible for extension or delays in the scheduled deliveries or periods of performance under this contract as a result of the Contractor's obligations to correct deficiencies, nor shall there be any adjustment of the delivery schedule or period of performance as a result of such correction of deficiencies, except as may be agreed to by the Government in a supplemental agreement with adequate consideration.

SECTION B

(2) It is hereby specifically recognized and agreed by the parties hereto that this clause shall not be construed as obligating the Government to increase the contract target amounts, ceiling price, or firm fixed price.

f. Transportation Charges.

(1) When the Government returns supplies to the Contractor for correction or replacement pursuant to this clause, the Contractor shall be liable for transportation charges up to an amount equal to the cost of transportation by usual commercial method of shipment from the designated destination point under this contract to the Contractor's plant, in addition to any charges provided for by (2) below. The Contractor shall also bear the responsibility for the supplies while in transit.

(2) When compliance with the terms of this clause by the Contractor involves shipment of corrected or replacement supplies from the Contractor to the Government, the Contractor shall be liable for transportation charges up to an amount equal to the cost of transportation by the usual commercial method of shipment from the Contractor's plant to the designated destination point under this contract, in addition to any charges provided for by (1) above. The Contractor shall also bear the responsibility for the supplies while in transit.

(3) For the purpose of this paragraph the word "supplies" in the phrase "supplies while in transit" shall not include an aircraft.

g. Contractor Responsibility to Proceed with Correction or Replacement

If the Contractor does not agree to his responsibility to correct or replace the supplies delivered, he shall nevertheless proceed in accordance with the written request issued by the Contracting Officer under paragraph c. to correct or replace the defective or nonconforming supplies. In the event it is later determined that such supplies were not defective or nonconforming within the provisions of this clause, the contract target amounts, ceiling price, or firm fixed price will be equitably adjusted. Failure to agree to such an equitable adjustment shall be a dispute concerning a question of fact within the meaning of the clause of this contract entitled "Disputes."

SECTION H

h. Correction of Deficient Replacement and Re-performances

Any supplies or parts thereof corrected or furnished in replacement and any services re-performed pursuant to this clause shall also be subject to all the provisions of the clause to the same extent as supplies or services initially accepted. The warranty with respect to such supplies, parts or services shall be equal in duration to that set forth in b.(2) above, and shall apply from the date of delivery of such corrected or replaced supplies.

i. Incentive Price Revision (if applicable)

All costs incurred or estimated to be incurred by the Contractor in complying with this clause shall be considered when negotiating the total final price under the Incentive Price Revision clause of this contract. After establishment of the total final price, Contractor compliance with this clause shall be at no increase in the total final price. Any equitable adjustments made pursuant to this clause shall be governed by the paragraph entitled "Equitable Adjustments Under Other Clauses" in the Incentive Price Revision clause of this contract.

67. NOTICE TO THE PRINCIPAL CONTRACTING OFFICER

a. The Contractor agrees to furnish, commencing on 1 April 1985 and thereafter at quarterly intervals, a written statement to the Principal Contracting Officer stating either (1) that no circumstances have occurred which would be a basis for requesting an adjustment in target cost, target profit, target price, ceiling price, Firm Fixed Price, delivery schedules, or any other terms and conditions of the contract, or (2) what circumstances (regardless of their nature or who was responsible for them) have occurred which may cause the submission of a request for adjustment in cost, fee, delivery schedule, or any of the other terms and conditions of

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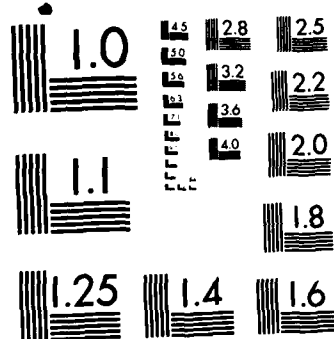
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